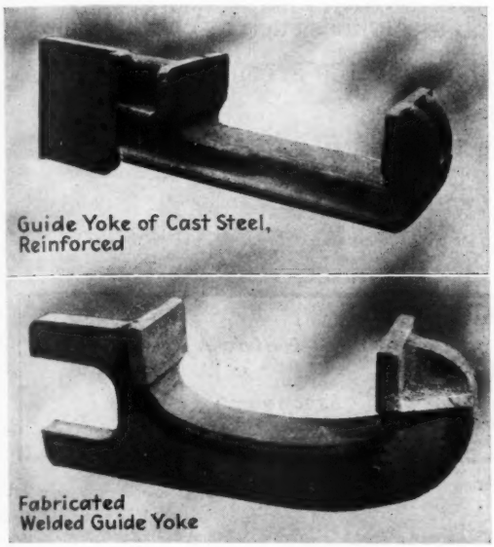
WELDED CONSTRUCTION REDUCES MACHINING TIME

Welded construction requires less machining whenever standard rolled steel shapes and plates can be used, since they can be furnished by the mill or supplier in required sizes and thicknesses to meet design specifications or flame cut to size. Welded construction also requires less machining than does riveted construction since the latter requires drilled or punched holes for rivets.

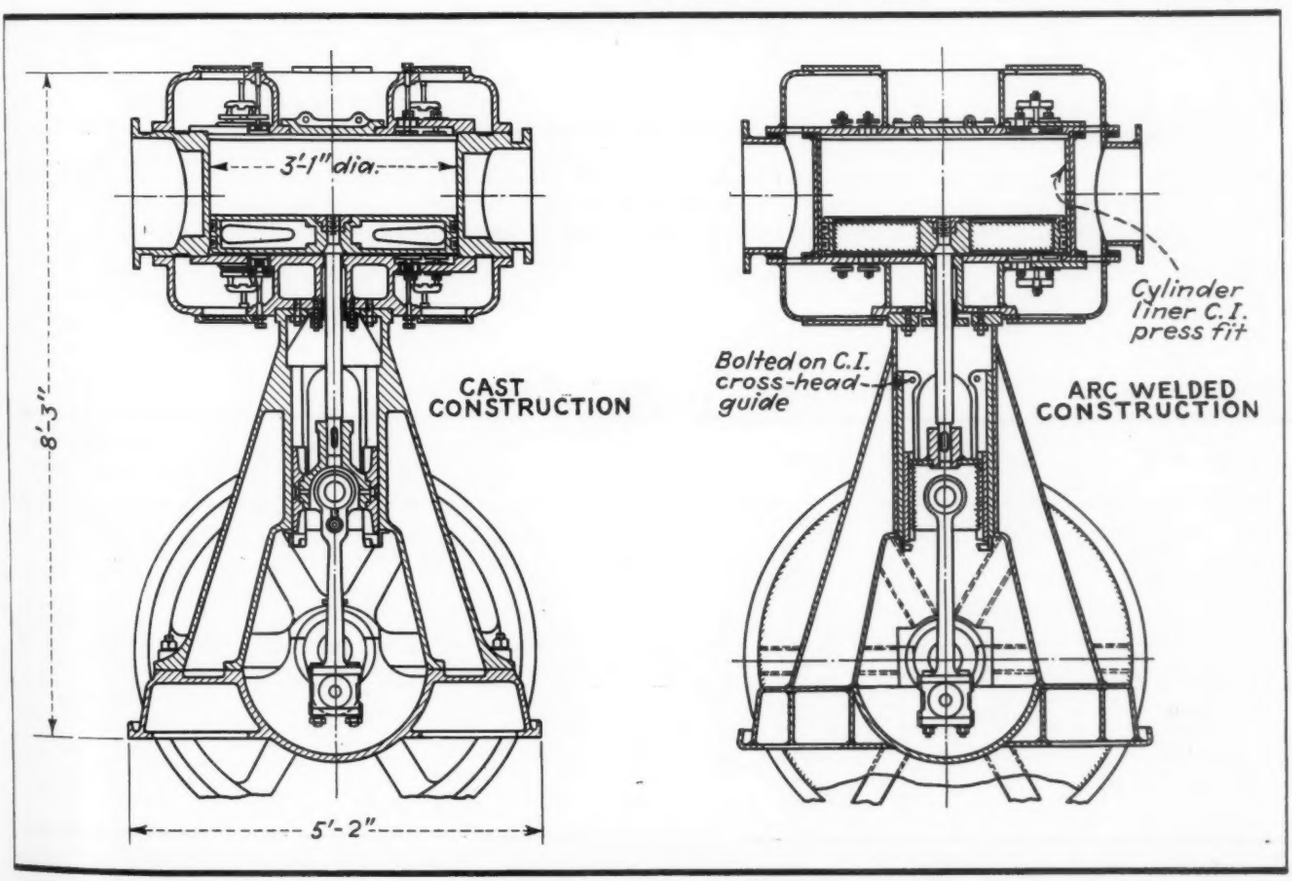


Machining Time Saved by Welded Construction

Industrial case studies by design engineers as submitted to the James F. Lincoln Arc Welding Foundation

Product Structure or Part	Machining Time, Hours		Machining Saved With Welded Construction	
	Former Construction	Welded Construction	Hours	Percent
Deep well pump	40	24	16	40
Locomotive guide yoke	26	20	6	23
Dust collecting bench	65	35	30	46
Copper sheet coiling machine	160	128	32	20
Oil well spudder housing	131	100	31	23½
Vacuum pump	309	178	131	42

Comparison of the designs of the cast and the welded vacuum pump

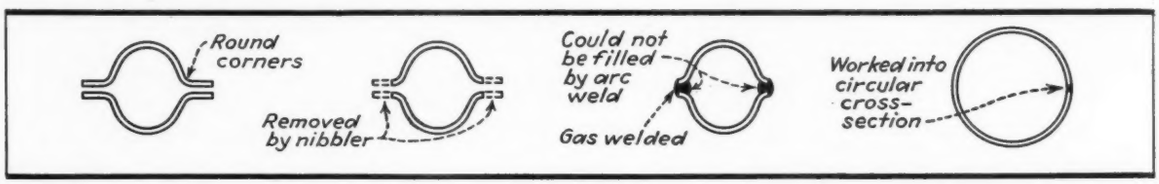


ARC WELDING THIN SHEETS

Uniformly good arc welds in sheets less than 0.050 in. (18 gage) thick have been difficult to attain because of the low currents and arc stability required. Generator type welders are now available with a minimum setting of 10 to 15 amp. with stable operation at 20 amp. and higher for making good welds in thin sheets. Stainless steel and Monel exhaust stacks and manifolds for aircraft, which are of comparatively thin gage, are being fabricated by this method. More recently the method has been approved for aircraft use in bench assemblies such as control parts. Tests on two aircraft materials, S.A.E. 1025 and 4130, are shown in the accompanying tables.

Tubular Section Formed of Thin Gage Stainless Steel

A. Operations when plaster die formed parts are used



B. Operations when steel or hard aluminum-bronze dies are used

By using metal dies sharper corners can be formed and nibbling operation eliminated. By shearing off excess material, section can be arc welded in less time than before. As an example of time saving, identical aileron bell cranks have been welded in 12 min. by gas and in 3 min. by electric arc.

Results of Tests on Welded Thin Tubes

Specimen	Material	Thickness	Current	Electrode Inches Dia.	Failure*	Average Unit Tensile Stress
Tubing (1 in. dia.)	1025	0.035	18	3/64	O	81,950
	....	0.049	27	1/16	O	80,600
	....	0.065	32	1/16	I	75,200
	4130	0.035	18	3/64	I	94,250
	....	0.049	26	1/16	I	104,900
	....	0.065	32	1/16	I	82,600
Sheet	1025	0.187	73	1/8	I	57,260
Specimen (¾ in. wide)	4130	0.035	23	1/16	O	113,500
	....	0.049	29	1/16	I	103,430
	....	0.187	65	3/32	I	57,260

* I — in weld O — outside weld

Rod Size and Amperage for Welding Thin Gage Material

(Approximate)

Electrode Dia. (in.)	Welding Current (amp.)	Gage of Material
1/32	5–10	32–26
3/64	10–20	26–20
1/16	20–40	20–14
3/32	40–60	14–10
1/8	60–75	10–¼ in.

Minimum Tensile Strength of Welds for Welder Qualification Tests

(Air Corps Spec. 20013-B)

Carbon Content of Filler Rod	Carbon Steel Base Metal	Alloy Steel Base Metal
Up to 0.06.....	45,000	55,000
0.07–0.12.....	50,000	65,000
Over 0.12.....	55,000	70,000

S.A.E. 4340 NOW SUCCESSFULLY WELDED

By welding, quenching and tempering after gas welding, S.A.E. 4340 tubes can be butt welded to give a tensile strength of more than 180,000 lb. per sq. in. with a Rockwell hardness of C 46. It is considered that a minimum tensile strength of 125,000 lb. per sq. in. can be safely specified for parts made by gas welding S.A.E. 4340 steel tubes and normalizing.

As shown in the accompanying table, butt welded specimens of S.A.E. 4340 tubes can be heat-treated to develop a maximum tensile strength of 217,000 lb. per sq. in. as compared with a maximum tensile strength of 252,800 lb. per sq. in. for the unwelded tube. The gas welding characteristics of this material are equal to or better than those of S.A.E. 4130 steel tubes.

Results of Tension Tests, Butt Welded 4340 Steel Tubes

1¾ in. O.D. x 0.65 in. Wall

Specimen No.	Condition	Tensile Strength lb. per sq. in.	Rockwell Hardness (Base Metal)
19	Annealed and welded	99,000	B 91.0
20		98,700	B 91.5
Average		98,850	B 91.3
21	Welded " as received "	122,300	C 38.0
22		138,700	C 38.0
Average		130,500	C 38.0
23	Welded " as received " and	124,000	C 39.0
24	normalized	134,000	C 37.0
Average		129,000	C 38.0
25	Welded " as received," oil	217,000	C 51.0
26	quenched 1,525 deg. F., tempered 400 deg. F.	211,500	C 51.0
Average		214,250	C 51.0

Note: All specimens except Nos. 19 and 20 broke in or adjacent to the weld.

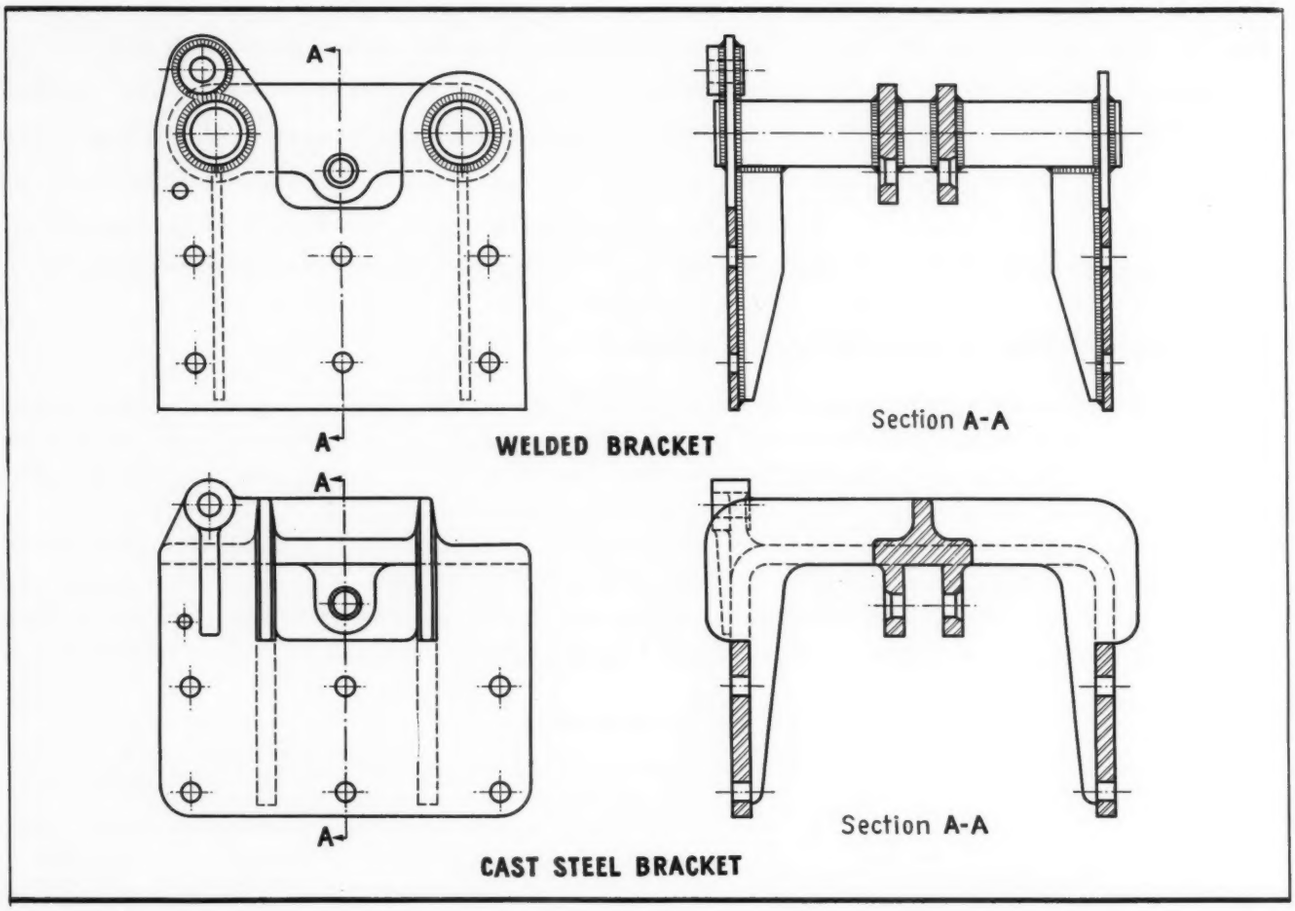
Results of Tension Tests, Butt Welded 4340 Steel Tubes

2¼ in. O.D. x 0.125 in. Wall

Specimen No.	Tensile Strength lb. per sq. in.	Rockwell Hardness (Base Metal)
As Welded		
1	128,300	C 36.0
2	136,000	C 36.5
3	131,200	C 36.0
4	135,500	C 36.5
5	139,900	C 36.5
6	145,500	C 37.5
Average	136,000	C 36.5
Welded and Normalized		
7	135,000	C 40.5
8	125,700	C 36.5
9	130,800	C 42.5
10	133,900	C 38.0
11	134,800	C 43.5
12	137,500	C 38.5
Average	132,900	C 40.0
Welded, Quenched and Tempered		
13	175,000	C 45.0
14	171,000	C 46.5
15	182,000	C 46.0
16	167,000	C 46.0
17	199,000	C 46.0
18	204,000	C 47.0
Average	183,000	C 46.0

Notes: (1) Longitudinal bead welded on specimens Nos. 7 and 8. (2) All specimens broke in the weld.

Alternate Designs Offered by Army



Alternate designs are drawn up wherever possible by the War Department to speed production of ordnance parts. This permits a contractor to choose the alternate design which he can produce fastest and cheapest. Also, the use of alternate designs increases the list of manufacturers equipped to produce the given part. Fundamental dimensions and tolerances are the same for each alternate; in some cases the same blueprints can be used for both methods of production specified. Typical of this far-sighted design policy is the bracket shown above, which can be either built up as an arc-welded assembly of tubes and plates, or cast from steel and machined.

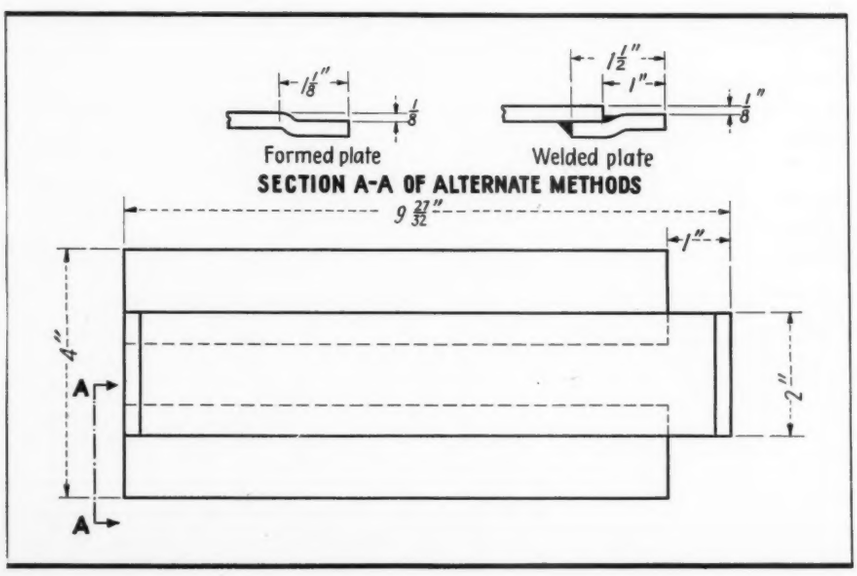
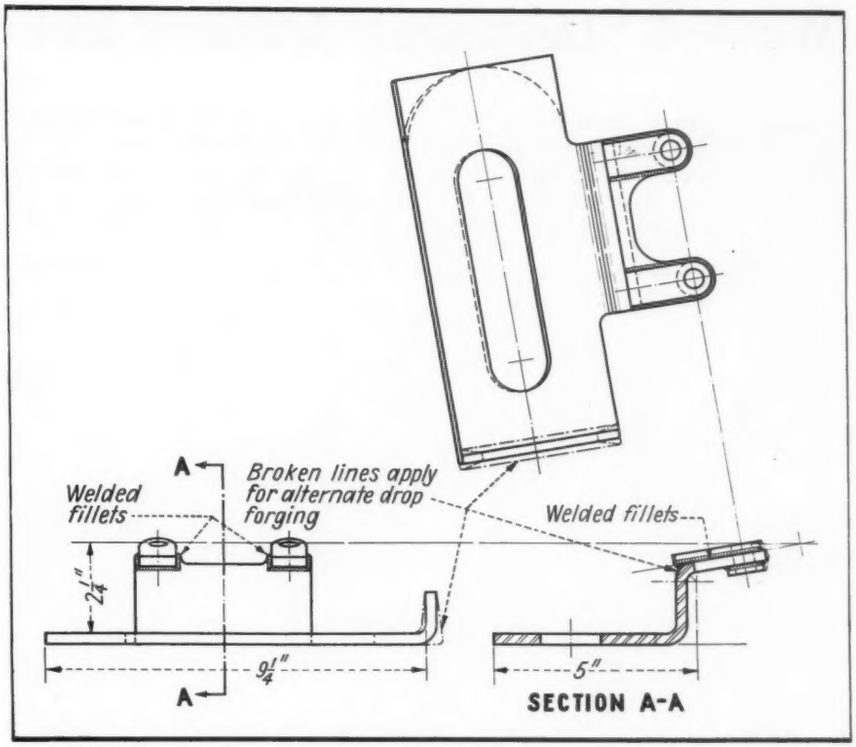
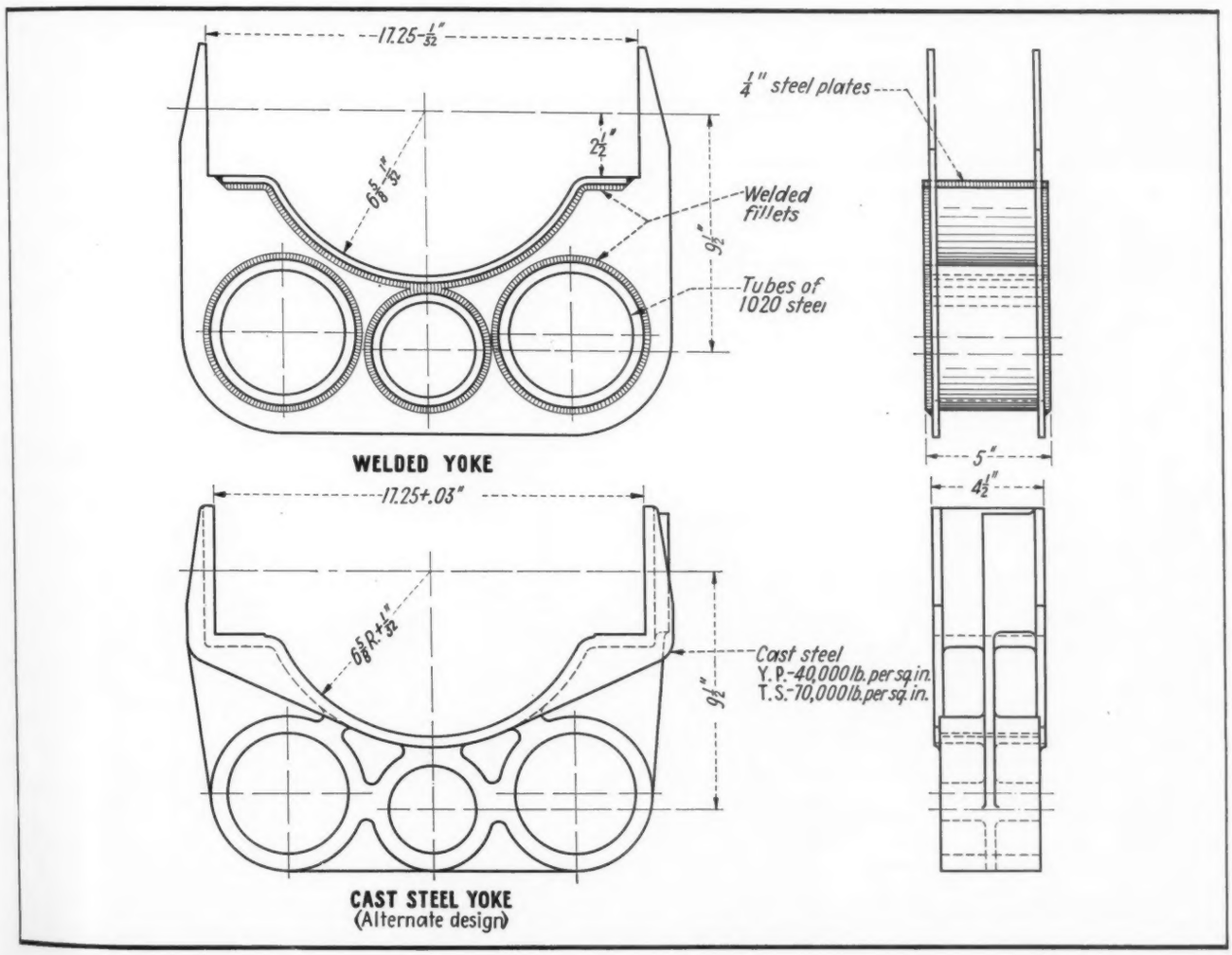


Plate for gun carriage is designed as shown so that it can be either welded or stamped. Choice of method depends upon the availability of equipment and labor in the individual sub-contractor's shop. One blueprint shows both methods.

Either welding or drop forging are acceptable methods for making this foot rest for Army ordnance equipment. What little differences there are between the welded and forged parts are shown by broken lines at right. Contractor may choose either method for reasons of economy and speed of production with his equipment.

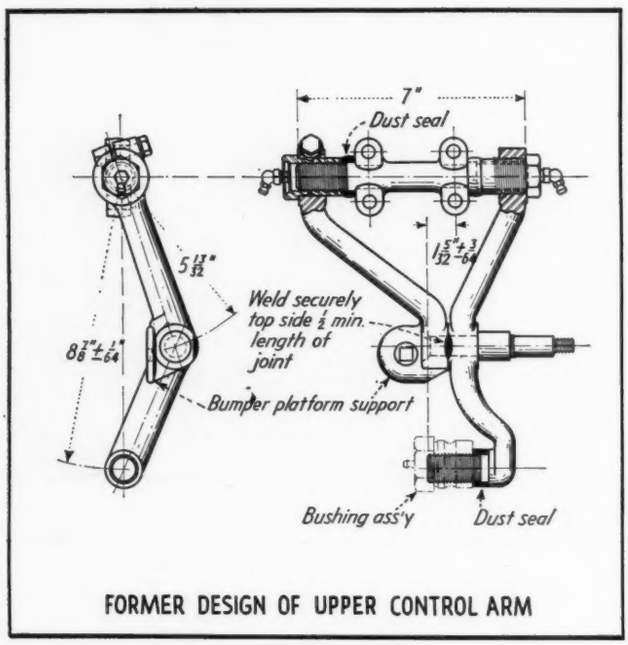


Welded or cast steel alternate designs are also given by Army design engineers of the Watertown Arsenal for this cradle yoke for anti-aircraft guns. Dimensions specified for both designs are identical, and except where otherwise indicated, 1/32 in. is specified for all tolerances.

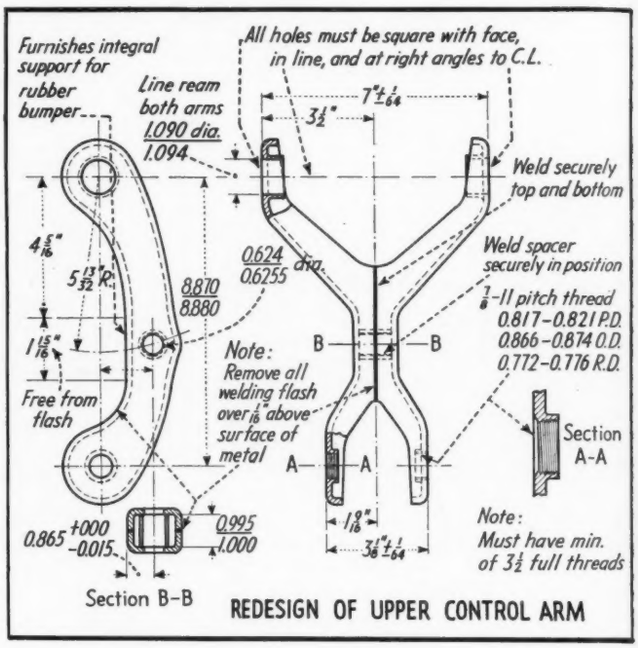


Welded Stampings Reduce Machining

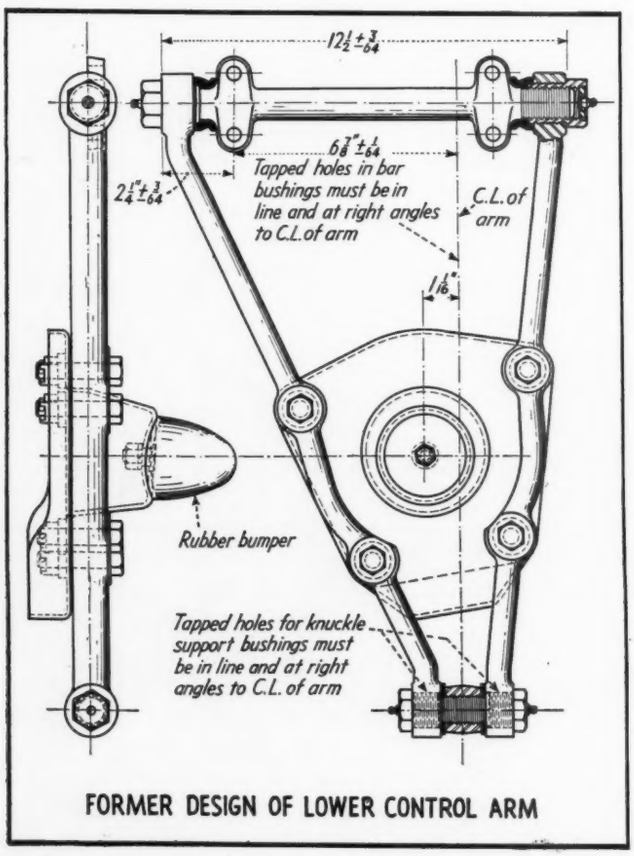
U-shaped steel stampings with flued holes saved cost and weight, reduced machining and assembly time, and increased strength and fatigue resistance of Chrysler lower and upper control arms of the front suspension. Formerly forged alloy steel, they required expensive dies, drilling and machining. Upper control arm is now two U-sections butt welded to form a box section at the center, replacing two forgings. Rubber bumper seats directly on assembly; with the forgings, a special bracket had to be forged integrally with the bar.



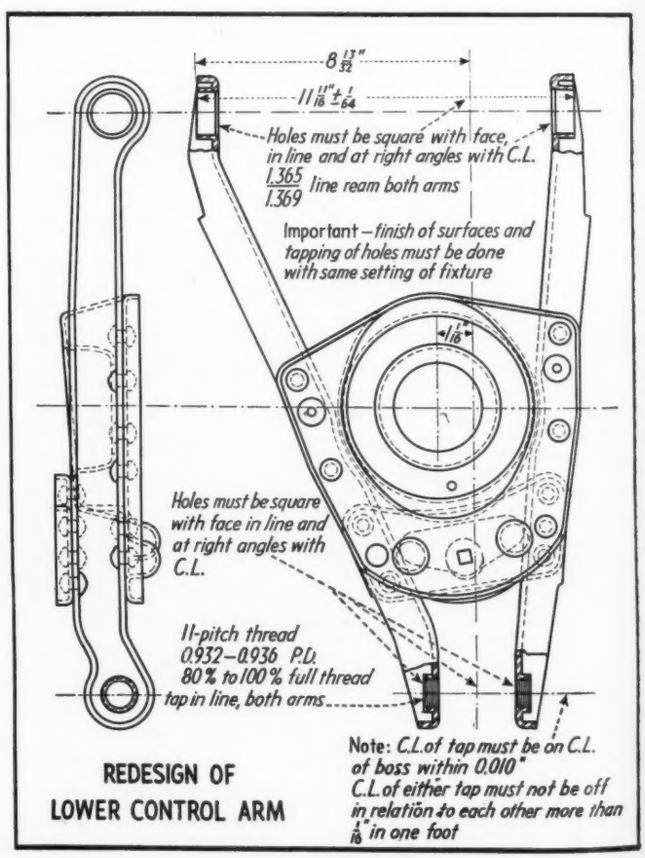
FORMER DESIGN OF UPPER CONTROL ARM



REDESIGN OF UPPER CONTROL ARM

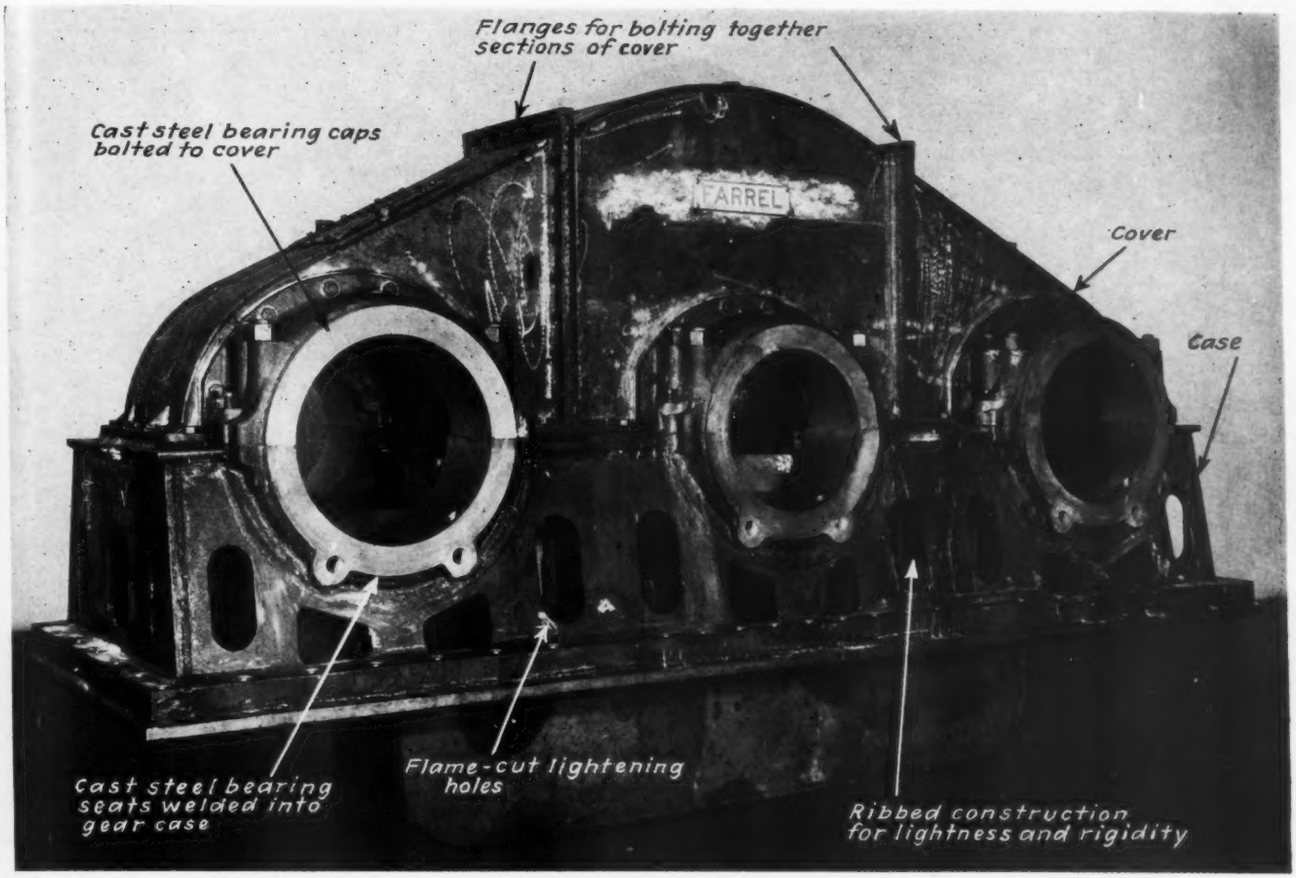

12½ ±3/64
6⅞" ±1/64
Tapped holes in bar bushings must be in line and at right angles to C.L. of arm
C.L. of arm
2¼" ±3/64
1/16"
Rubber bumper
Tapped holes for knuckle support bushings must be in line and at right angles to C.L. of arm

FORMER DESIGN OF LOWER CONTROL ARM

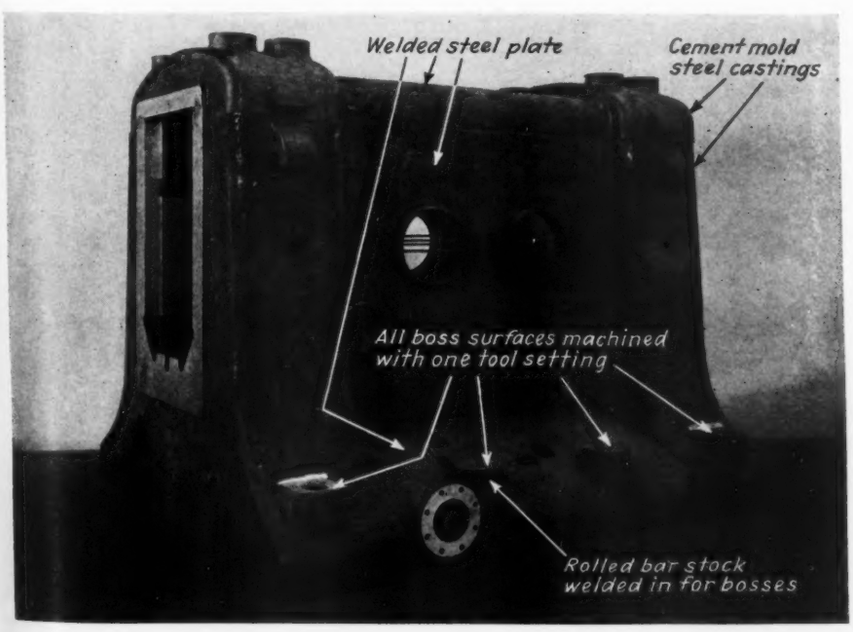

8 13/32"
11 11/16" ±1/64
Holes must be square with face, in line and at right angles with C.L.
1.365
1.369
line ream both arms
Important – finish of surfaces and tapping of holes must be done with same setting of fixture
1/16"
Holes must be square with face in line and at right angles with C.L.
11-pitch thread
0.932–0.936 P.D.
80% to 100% full thread
tap in line, both arms
Note: C.L. of tap must be on C.L. of boss within 0.010"
C.L. of either tap must not be off in relation to each other more than 1/16" in one foot

REDESIGN OF LOWER CONTROL ARM

Castings and Plate in Welded Structures


Flanges for bolting together sections of cover
Cast steel bearing caps bolted to cover
FARREL
Cover
Case
Cast steel bearing seats welded into gear case
Flame-cut lightening holes
Ribbed construction for lightness and rigidity

Certain sections of heavy machinery often can be produced easiest by casting, while other sections can be fabricated best by welding. Farrel-Birmingham Company takes advantage of both methods when designing large housings for reduction gear drives by combining steel castings and steel plate in large welded structures. Housing for oil tanker reduction gears, shown above, is a typical design. Case and cover are rolled steel plate; ribbed to give rigidity. Welded three part cover is assembled by bolting to facilitate service inspection. Welded on bearing seats and bolted on caps, on each side of case, are separate steel castings. The ship propulsion unit consists of two 700 hp., 400 r.p.m. diesel engines which drive a central reduction gear at 125 r.p.m., coupled to propeller shaft.


Welded steel plate
Cement mold steel castings
All boss surfaces machined with one tool setting
Rolled bar stock welded in for bosses

Rolled steel plate and steel castings welded together contribute to speedier production and reduced weight of this 4,000 hp. pinion stand designed by Farrel-Birmingham Company for a cold strip finishing mill. Two end pedestals of the stand are steel castings, while the center section is fabricated from 2-in. steel plate. Horizontal stiffener plates are inside the structure. The cap similarly is constructed by welding cast steel ends to steel plate center section. In welding steel castings to steel plate, carbon content of casting should be held below 0.25 percent and manganese content should be low.

Resistance Weldability of Aluminum Alloys

	Non-heat-treatable alloys			Heat-treatable Alloys				Casting Alloys		Notes
	2S	3S	52S	53S	61S	Alclad 17S	Alclad 24S	43	47	Hard tempers preferred to full annealed tempers. Permanent mold castings.
1. Weldability	Good	Good	Fair	Good	Good	Fair	Fair	Fair	Good	"Fair" welds subject to porosity and cracks unless close control exercised over all factors.
2. Thickness weldable	0.003″–0.187″	0.003″–0.187″	0.010″–0.187″	0.010″–0.187″	0.010″–0.187″	Note 1 0.010″–0.102″	Note 1 0.010″–0.081″	0.050″–0.125″	0.050″–0.125″	Capacity of equipment may further limit thickness. Note 1. Brittle welds in greater thickness.
3. Maximum difference in thickness in 2-ply joint in number of B & S Gage Nos.	8	8	8	8	8	6	6	6	6	Larger difference permitted if domed tip used against thinner member.
4. Number of plys that can be welded simultaneously	2–4	2–4	2–4	2–4	2–4	2–3	2–3	2	2	Depends somewhat on thickness and arrangement of plys.
5. Suggested type of equipment	A.C.	A.C.	Inductance or condenser or A.C.	Inductance or condenser or A.C.	Inductance or condenser or A.C.	Inductance or condenser or A.C.	Inductance or condenser or A.C.	A.C.	A.C.	
6. Maximum variation in welding current	±5%	±5%	±5%	±5%	±5%	±2½%	±2½%	±5%	±5%	
7. Maximum variation in welding pressure	±5%	±5%	±5%	±5%	±5%	±2½%	±2½%	±5%	±5%	
8. Time control — for A.C. welding only	Contactor ± 1 cycle	Contactor ± 1 cycle	Contactor ± 1 cycle	Contactor ± 1 cycle	Contactor ± 1 cycle	Synchronous control −0, + 1 cycle	Synchronous −0, + 1 cycle	Contactor ± 1 cycle	Contactor ± 1 cycle	Better results with synchronous control of welding time.
9. Welding electrode material R.W.M.A. specifications	Group A Class 1	Group A Class 1	Group A Class 1	Group A Class 1	Group A Class 1	Group A Class 1	Group A Class 1	Group A Class 1	Group A Class 1	Group A, Class 2, or Class 3 sometimes used to increase penetration of weld toward that electrode.
10. Recommended cleaning procedure for material to be welded	Remove oil and dirt	Remove oil and dirt	Cleaning method 1, 2, 3, or 4	Cleaning method 1, 2, 3, or 4	Cleaning method 1, 2, 3, or 4	Cleaning method 1, 2, 3, or 4	Cleaning method 1, 2, 3, or 4	Remove flash and burrs	Remove flash and burrs	Cleaning by method 1, 2, 3 or 4 always produces sounder and more consistent welds.
11. Cleaning procedure after welding	None required	.....	.....	.....	.....	.....	.....	.....	.....	Where invisible welds are required spots must be sanded or rubbed with steel wool.
12. Cleaning of electrodes required after	10–40 welds	15–60 welds	8–30 welds	10–40 welds	10–40 welds	10–40 welds	10–40 welds	8–15 welds	10–20 welds	Varies with different welding machines. Inductance or condenser welders will produce from 3 to 10 times, the number of welds before cleaning of electrodes is required.

Four Surface Preparations for Spot Welding

METHOD I

1. Dip parts in 50 percent HNO_3 cold for 15 seconds.*
2. Rinse in cold water.*
3. Dip parts in 5 percent NaOH + 4 percent NaF at 160 deg. F. for 30 seconds.
4. Rinse in cold water.
5. Dip parts in 50 percent HNO_3 cold for 15 to 30 seconds to remove black deposit from step 3.
6. Rinse in cold water.**
7. Rinse in boiling water.***
8. Dry parts on steam coils or in sawdust.

METHOD II

1. Dip parts in 50 percent HNO_3 cold for 15 seconds.*
2. Rinse in cold water.*
3. Dip parts in 10 percent NaOH at 160 deg. F. for 30 seconds.
4. Rinse in cold water.
5. Dip parts in 50 percent HNO_3 cold for 15 to 30 seconds to remove black deposit from step 3.
6. Rinse in cold water.**
7. Rinse in boiling water.***
8. Dry parts on steam coil or in sawdust.

METHOD III

1. Paint area to be welded with gum tragacanth HF acid paste and leave on for 30 seconds.
2. Wash paste off with running cold water or with wet rags.
3. Dry off water with dry rags.

Gum tragacanth paste is prepared from:

3 lb. gum tragacanth
10 gal. hot water

Dissolve gum tragacanth in hot water, add one gallon of alcohol to water if necessary to dissolve gum tragacanth.

Add 10 lb. of hydrofluoric acid to above solution.

Material must be stored in paraffine-lined containers.

Operators must wear rubber gloves and goggles to use this material. In partially assembled parts precautions should be taken to keep acid out of joint.

METHOD IV

Area to be spot welded may be cleaned by mechanical means.

(a) Rub with steel wool.
(b) Rub with fine emery cloth.
(c) Use fine wire brush.

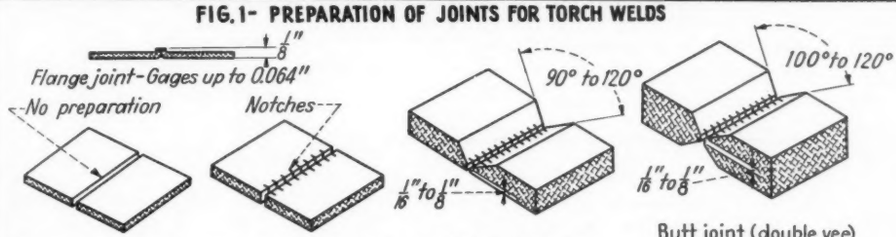
*Omit steps 1 and 2 for material relatively free from oil.

**Repeat steps 3 to 6 for material having very heavy heat-treating film not removed in steps 1 to 6.

***Final hot water should be thoroughly free of dissolved salts and of organic matter which would tend to stain the freshly cleaned parts.

Fusion Welding Characteristics of Aluminum Alloys

FIG. 1- PREPARATION OF JOINTS FOR TORCH WELDS


1/8"
Flange joint-Gages up to 0.064"
No preparation
Notches
90° to 120°
100° to 120°
1/16" to 1/8"
1/16" to 1/8"
Butt joint-light gage up to 0.057"
Butt joint (notched) 0.057" to 0.1875"
Butt joint (single vee) 0.188" and up
Butt joint (double vee) alternate design for gages 0.438 and up

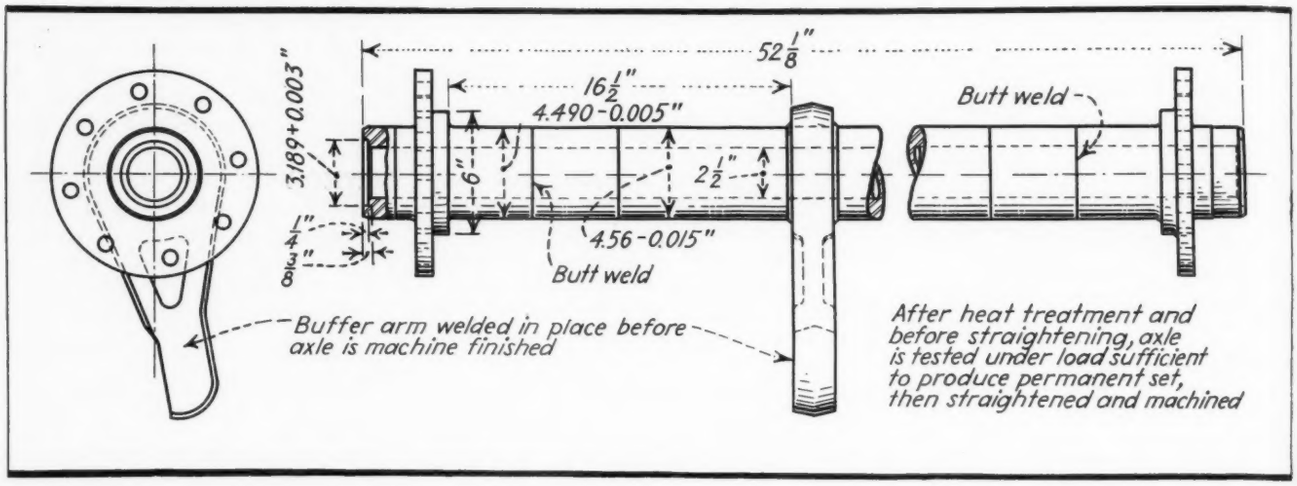
Notches made with cold chisel approx. 1/16" deep and 3/16" apart

FIG. 2- PREPARATION OF JOINTS FOR METALLIC ARC WELDING

Edge preparation for material thicker than 1/4" when welded from one side. No edge preparation is used for welding from one side, sheets thinner than 1/4 in.; or for welding from both sides, sheets up to 1/2 in. thick

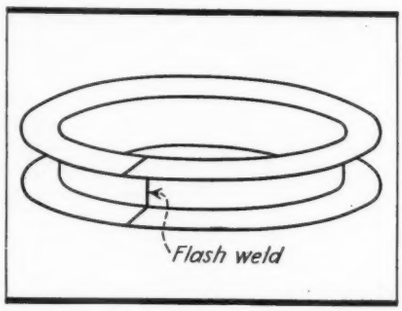
	Wrought Alloys							Casting Alloys				
	Non-heat-treatable			Heat-treatable				Non-heat-treatable				Heat-treatable
	2A	3S	52S	53S	61S	Alc. 17S	Alc. 24S	43	214	B214	406	356
Gas Welding with Oxygen-Acetylene or Oxygen-Hydrogen with No. 22 Flux												
1. Weldability	Good	Good	Good	Good	Good	Poor	Poor	Good	Fair	Good	Good	Fair
2. Thickness weldable	Practical minimum 0.030 in.— maximum 1 in.											
3. Weld wire	2S	2S	43S	43S	43S	...	...	43	43	43	2S	43
4. Joint preparation	See Fig. 1											
5. Max. pre-heat temp.	750	750	750	400	400	...	...	750	750	750	750	400
6. Finishing welds	Hammer	Hammer	Grind	Grind	Grind	...	...	Grind	Grind	Grind	Grind	Grind
Metallic Arc Welding with No. 43 Flux Coated Electrodes — For sheets 12 gage and thicker												
1. Weldability	Good	Good	Good	Good	Good	Poor	Poor	Good	Good	Good	Good	Good
2. Joint preparation	None up to 1/4 in. sheet — See Fig. 2											
Carbon Arc with Thin Coat of No. 25 Flux Thoroughly Dried on Rods — For sheets 20 to 14 gage												
1. Weldability	Good	Good	Good	Good	Good	Poor	Poor	No applications have been made				
2. Type of joint	Well adapted to butt and simple lap joints											
3. Filler wire	2S	2S	43S	43S	43S	...	...					
4. Max. pre-heat temp.	400	400	400	400	400	...	...					
5. Joint preparation	None up to 1/8 in. (max. for manual application)											
Atomic Hydrogen with No. 22 Flux — For sheets 0.040 in. and thicker												
1. Weldability	Good	Good	Good	Good	Good	Poor	Poor	Good	Good	Good	Good	Good
2. Filler wire	2S	2S	43S	43S	43S	...	.....	43S	43S	43S	43S	43S
3. Joint preparation	Same as for torch welding — See Fig. 1											
4. Max. pre-heat temp.	750	750	750	400	400	...	...	750	750	750	750	400

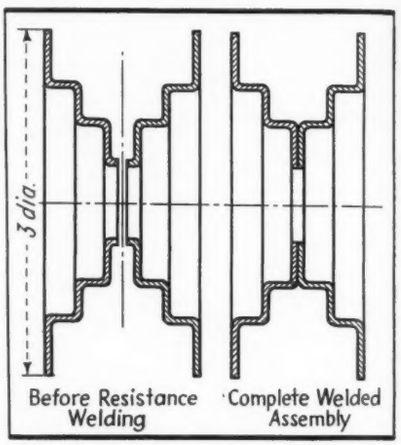
Economies with Resistance Welding



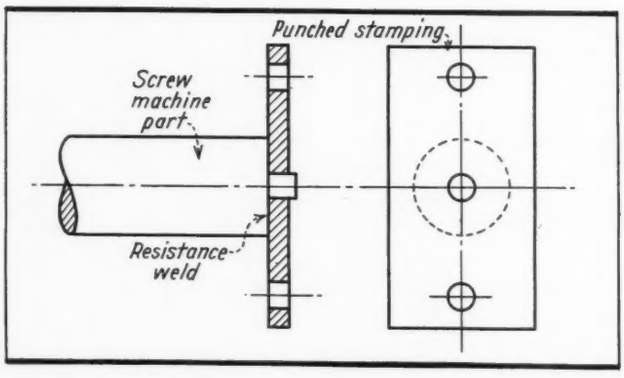
Bogie axle for anti-aircraft gun carriage has a flange at each end which ordinarily would call for machining 10-in. dia. stock down to the 4.56 in. smaller dia. for the greater part of the axle length. Most of that lathe work was eliminated by designing the axle in three parts, rough machining the flanged ends separately and butt welding them to the center part which is machined from stock of smaller diameter. Buffer arm is previously assembled on small diameter of axle by fillet welding. Finish machining is done on the built-up axle after heat-treatment, testing and straightening.

Expansion rings previously made from the cylindrical section of deep-drawn stainless steel cups, two rings being cut from the walls of each cup. The remaining metal was scrapped. In the design shown here, stainless steel strip is roll formed into a channel section and then wrapped around a mandrel. Each loop of the helix is then cut and the ends flash-welded together.

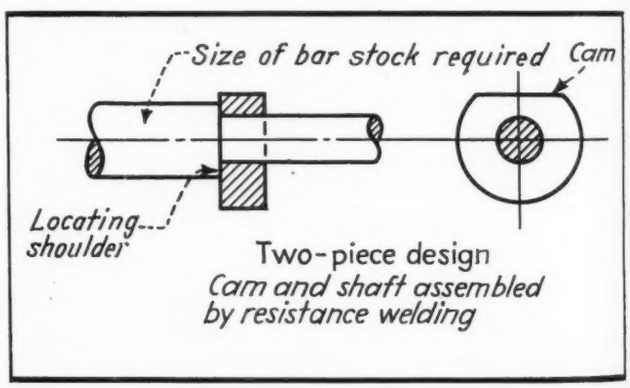




Small wheels and pulleys can be designed by combining two similar stampings in a resistance welding operation. Little machining is required.

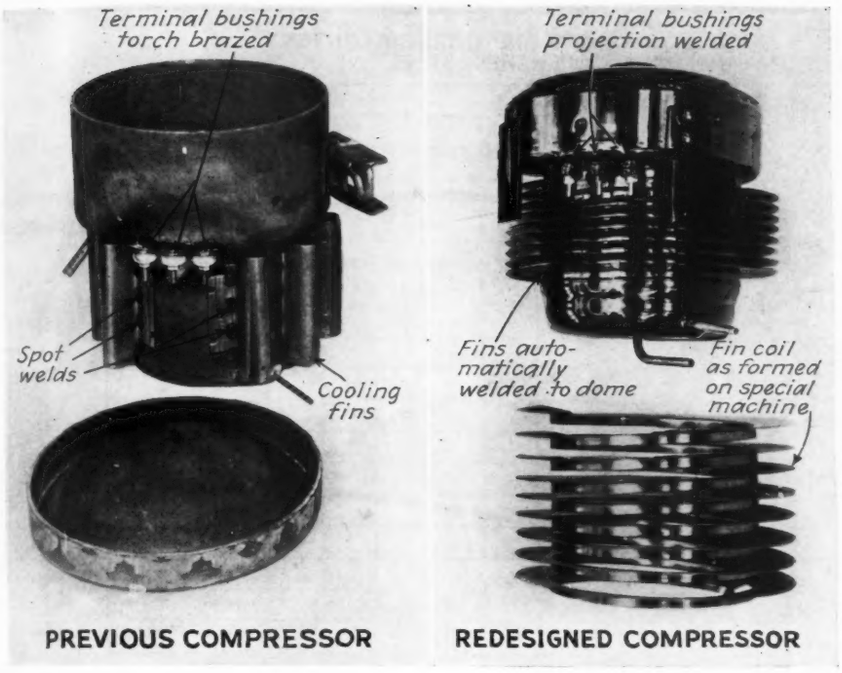


Stampings and screw machine parts resistance welded save much machining when large diameter flanges are required on a turned piece of relatively small diameter. To make the above part from a forging would be slow and expensive. In the design shown the punched stamping is resistance welded to the shaft or shank. Copper brazing might be used instead of resistance welding.

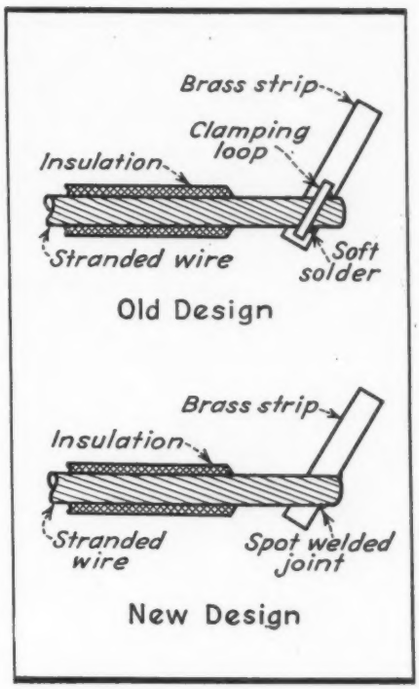


Camshaft and cam when made in one piece required bar stock of slightly larger diameter than the cam, also carburizing and grinding. Pieces often warped during carburizing so that a straightening operation was required. In design shown here, the cam and shaft are assembled by resistance welding. Cam points are Tocco hardened after assembly. Cam is made from S.A.E. 1040 stock.

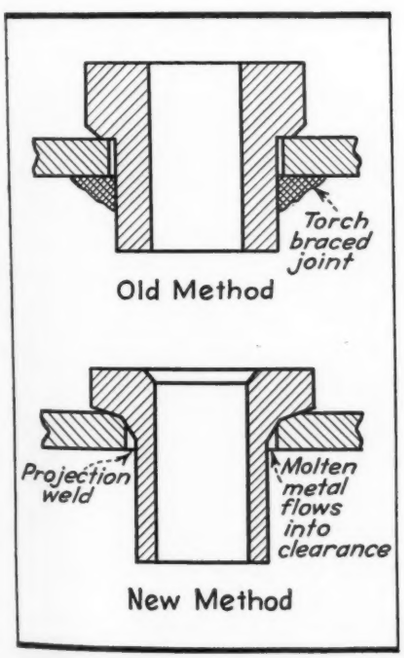
Redesigns for Rapid Welding

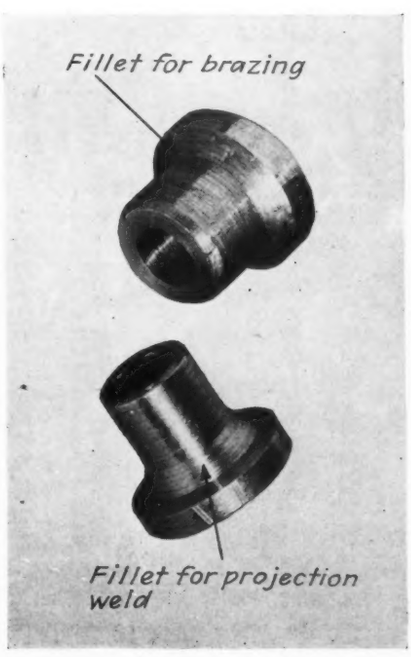


Improved resistance welding techniques at Westinghouse Electric & Mfg. Company have speeded production in assembling domestic refrigerator compressors. Cooling fins were previously formed as separate parts from sheet steel and then spot welded to the dome, as shown left. Present method is to roll steel strip into an unequal-angle section and then wind the formed strip into a helical coil of fins. Special strip forming and winding machine automatically cuts off coil at correct length. Fin coil is then slid over the dome and welded on a continuous seam welding machine; once started, welding is automatic. Fin helix and finished compressor are shown to the right. Seam welding also provides a better bond for heat transfer.



Spot welding replaces soldered joints and brazing in the manufacturing of shunts at Westinghouse Electric & Mfg. Company. The process consists essentially of welding by means of molybdenum tips while a stream of water plays on the stranded wire to prevent burning. No flux is necessary. Production is faster and flux and solder are eliminated in this improved design.



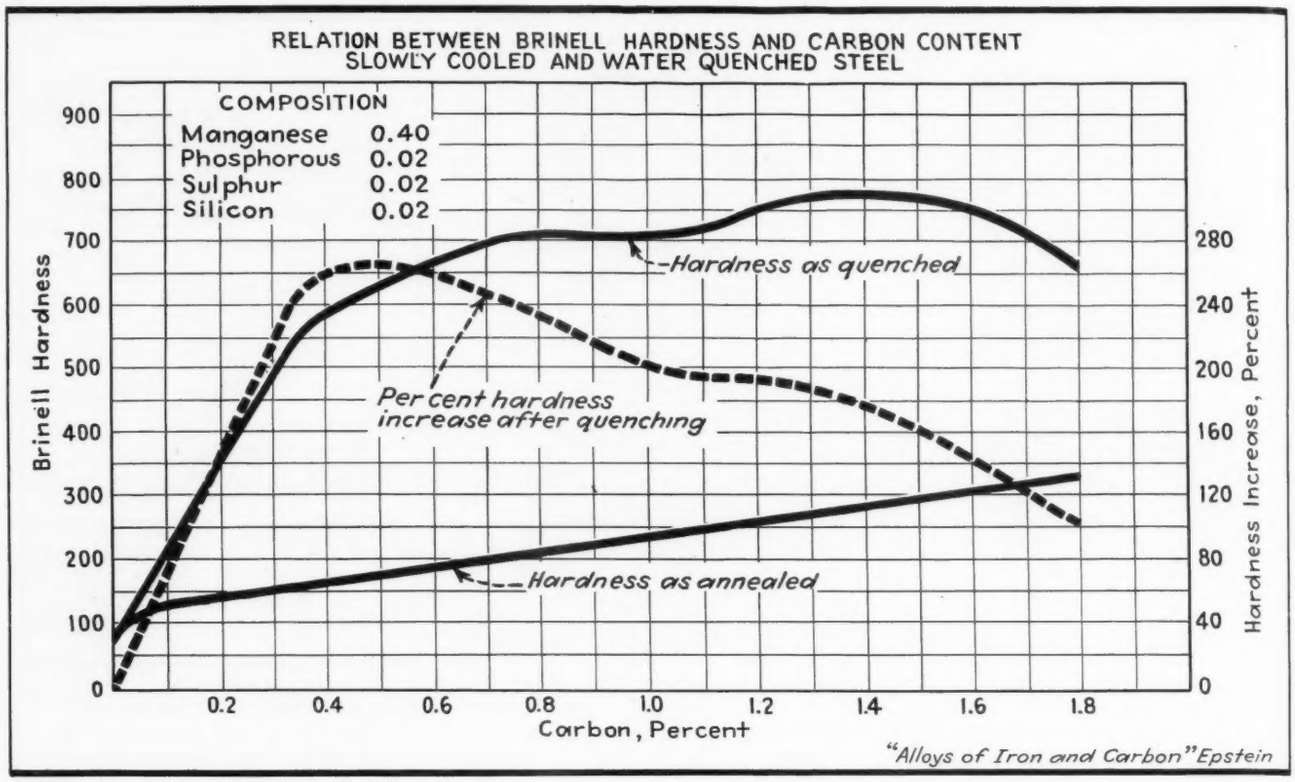


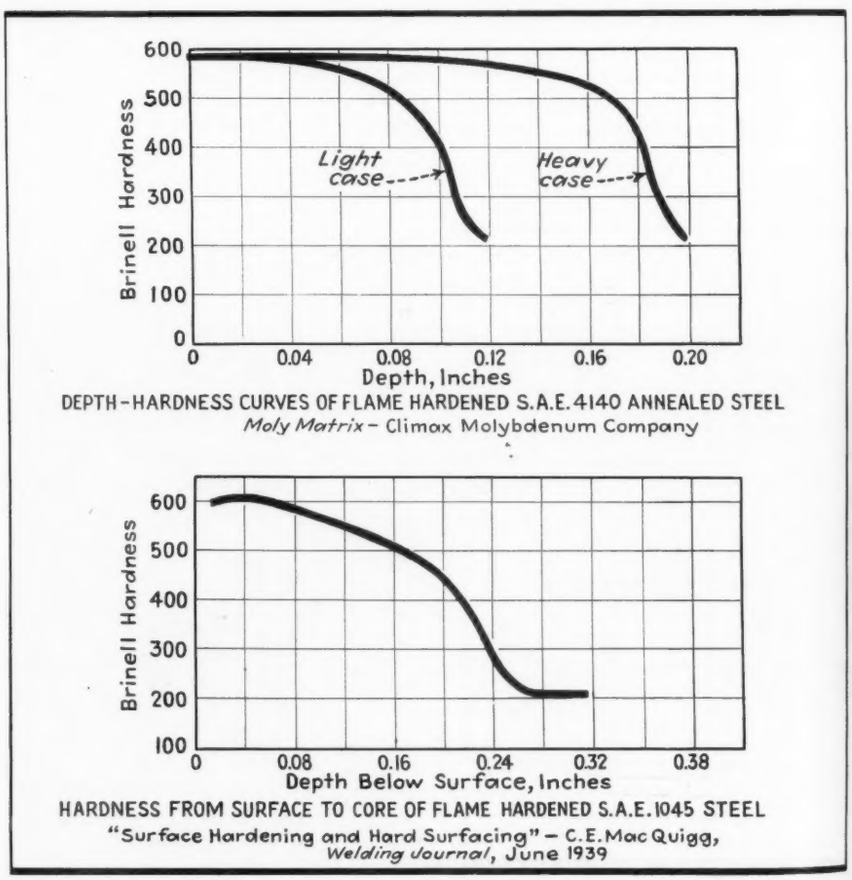
Projection welding of terminal bushing in Westinghouse refrigerator compressor eliminated difficult and unsatisfactory torch-brazing operation. The bushing, a screw machine product, was redesigned with a conical fillet to provide contact with edges of oversized punched hole in dome, as required for projection welding. As current and pressure are applied, molten metal flows into clearances, making a strong, fluid-tight joint. Shape and dimensions of fillet are important in projection welding of bushings.

PULSATION WELDING, with fully synchronous electronic control, is advantageous in resistance welding zinc-alloy die-castings. With the low melting point metals, better heat distribution and cooling with longer life of electrodes are obtained without overheating.

Flame Hardening Data

Courtesy Air Reduction Sales Company and The Linde Air Products Co.




Light case
Heavy case
Brinell Hardness
Depth, Inches
DEPTH-HARDNESS CURVES OF FLAME HARDENED S.A.E. 4140 ANNEALED STEEL
Moly Matrix - Climax Molybdenum Company
Brinell Hardness
Depth Below Surface, Inches
HARDNESS FROM SURFACE TO CORE OF FLAME HARDENED S.A.E. 1045 STEEL
"Surface Hardening and Hard Surfacing" - C.E. MacQuigg, Welding Journal, June 1939

Flame Hardening Specifications

Material—Cast iron, malleable iron and any alloy steels other than tool steels, with carbon content equal to S.A.E. 1040 or higher, depending on hardness desired.

Preparation—In order to assure freedom from surface cracking, the steel should be stress-relieved by annealing or normalizing before flame hardening.

Hardness Obtained—Surface hardness of the case will depend on the carbon content of the steel, as shown by the accompanying curves.

Depth of Hardness—Hardness varies with depth below the surface as shown by the curves.

Precautions — Avoid overheating, which is one of the prime causes of surface checking and cracks.

Reference literature—"Flame Hardening by the Oxy-Acetylene Process," published by the International Acetylene Association, 30 East 42nd Street, New York, N. Y. Price 20 cents.

Flame Cutting Data

Courtesy Air Reduction Sales Company and The Linde Air Products Company

Scope and Limitations

Thickness that can be cut—Any commercial thickness of steel plate and slabs up to about 12 in. thick.

Contours—Straight lines, circles or any irregular shapes provided inside radii are not less than ½ in. can be flame cut by machines.

Width of kerf, or metal removed, varies with thickness of plate as follows:

Thickness of plate (inches)	Approx. width of kerf (inches)
¼—⅜	$\frac{1}{16}$
½—2	$\frac{3}{32}$
2—6	⅛
6—9	$\frac{3}{16}$
9—12	¼

Effects of Flame Cutting

Steel containing less than 0.35 carbon can be cut without taking any special precautions. In general, steels that are satisfactory for fusion welding can be flame cut without causing any difficulties. Higher carbon steel will have a thin layer of hard steel formed on the flame cut surface. Preheating or reheating after flame cutting will prevent or eliminate the hardened surface.

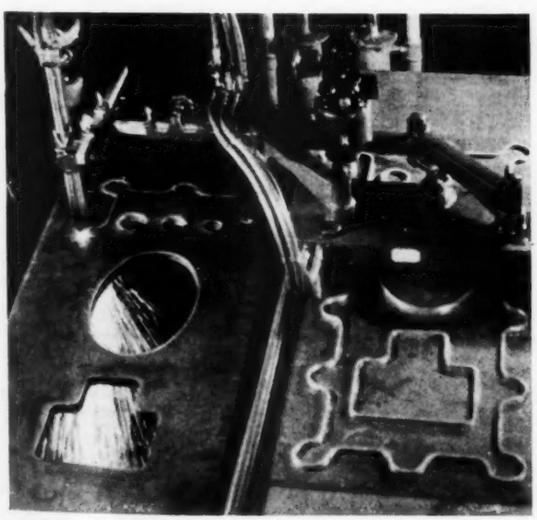
Identical parts can be produced most economically by stack cutting or multiple cutting.

Cutting speed—Approximate cutting speeds range from 2 ft. per min. for sheets up to ⅛ in. thick, to 21 in. per min. for ½ in. thickness, 16 in. per min. for 1 in. thickness, 12 in. per min. for 2 in. thickness, to 3 in. per min. for 12 in. thickness.

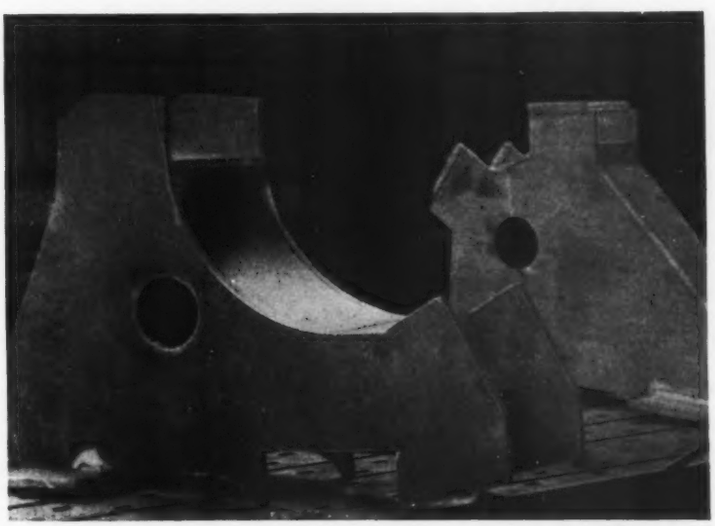
Tolerances—Squareness of cut can be held to $\frac{1}{32}$ in. for plates 6 in. thickness. This will be affected greatly by size of tip, gas pressure used, and other factors.

Reference literature—For a detailed discussion and data see Chapter 16, *Welding Handbook—1938*, published by the American Welding Society, 29 West 39th Street, New York, N. Y.

This 3-ton pitman was machine flame cut in a cutting time of approximately 3 hr. The pitman is 13 in. thick, 60 in. long, and 38 in. wide. Templet used to guide the tracing wheel is shown



Use of a guide track for the tracing wheel of the cutting machine permits fast and accurate cutting

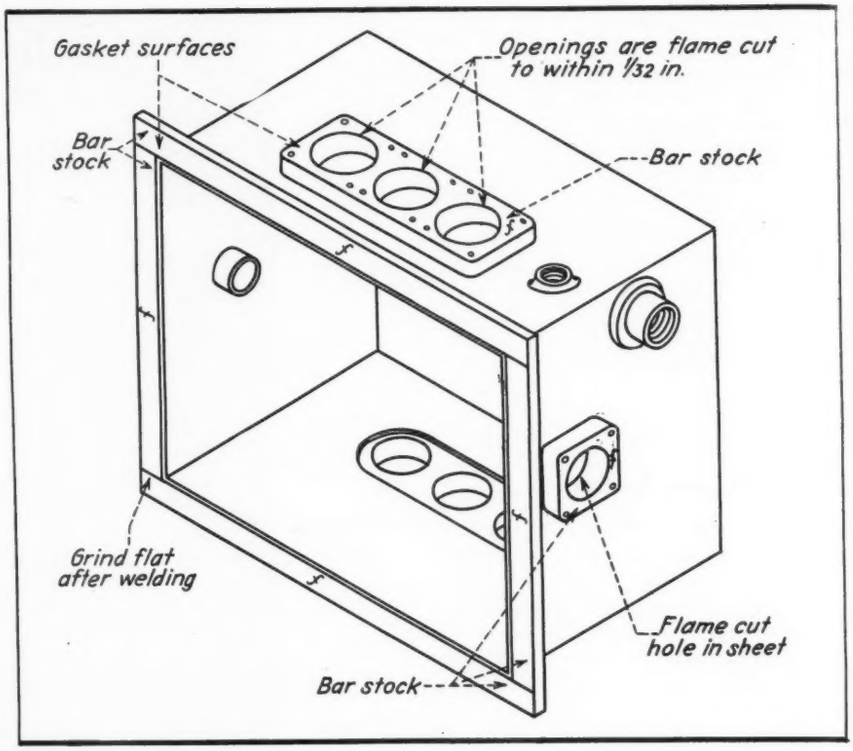


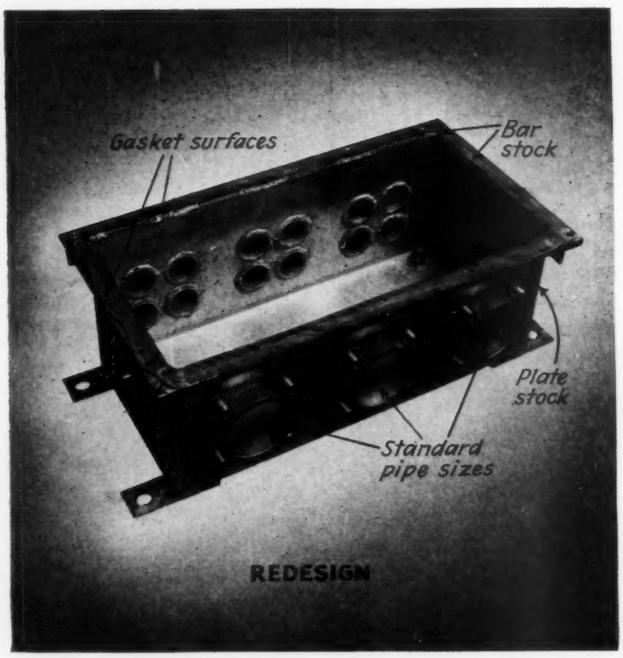
Sections of these journal rest frames, for a roll-grinding machine, were cut to shape by an oxy-acetylene cutting machine

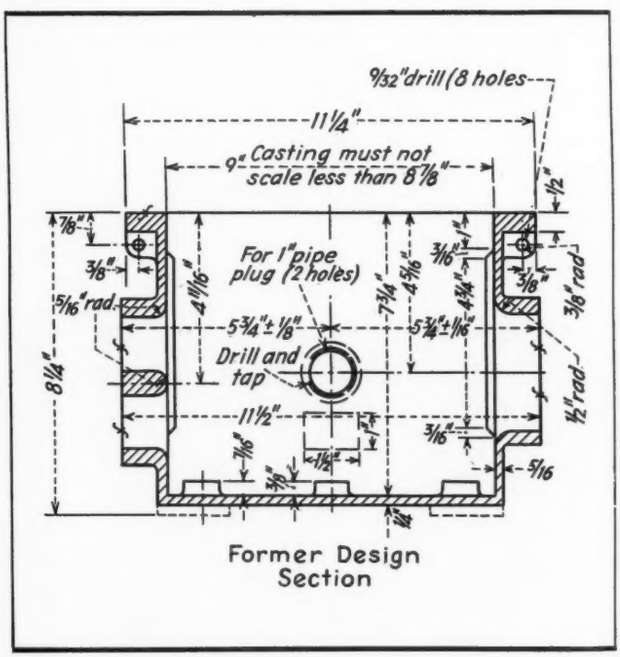
Welded – Flame Cut – Ground

Fifty Percent Cost Reduction Through Redesign

To accomplish savings in machining time on the G. & W. Electric Specialty Company tank, engineers utilized bar stock and welding. Previously, top and connection faces were bored and milled to furnish a flat surface for gaskets; large areas had to be machined in a horizontal milling machine. In the new design mild-steel bar stock welded as shown forms the top flange and the connecting plates on the sides. Openings are flame cut within 1/32 in. Top flange joints are welded. Only machining operation performed on the top surface is the grinding of the weld to a flat. Final cost of the new box is 50 percent of the cost of the original design.





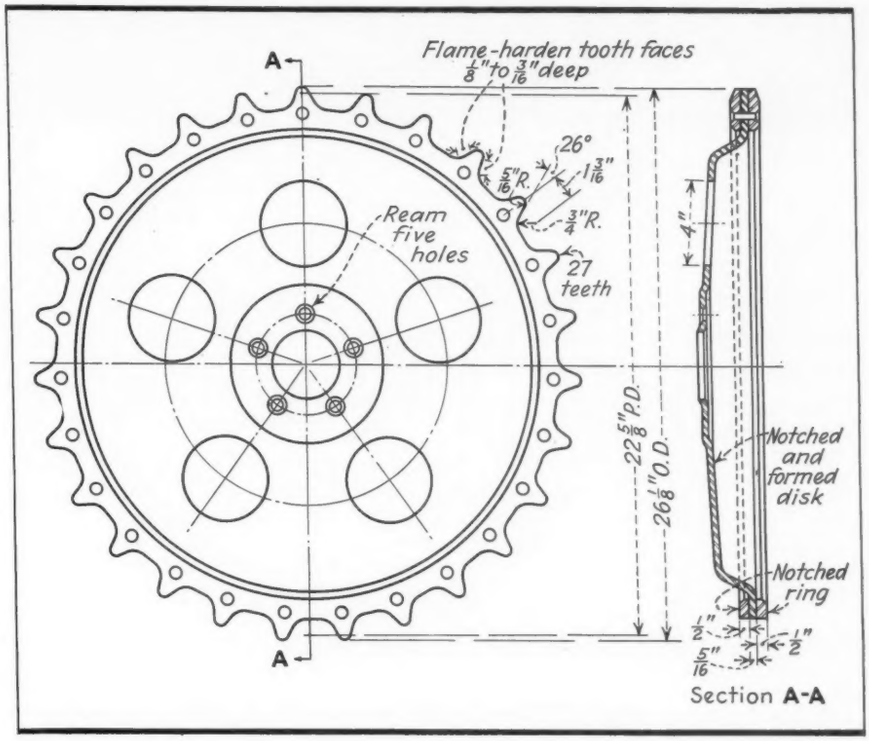


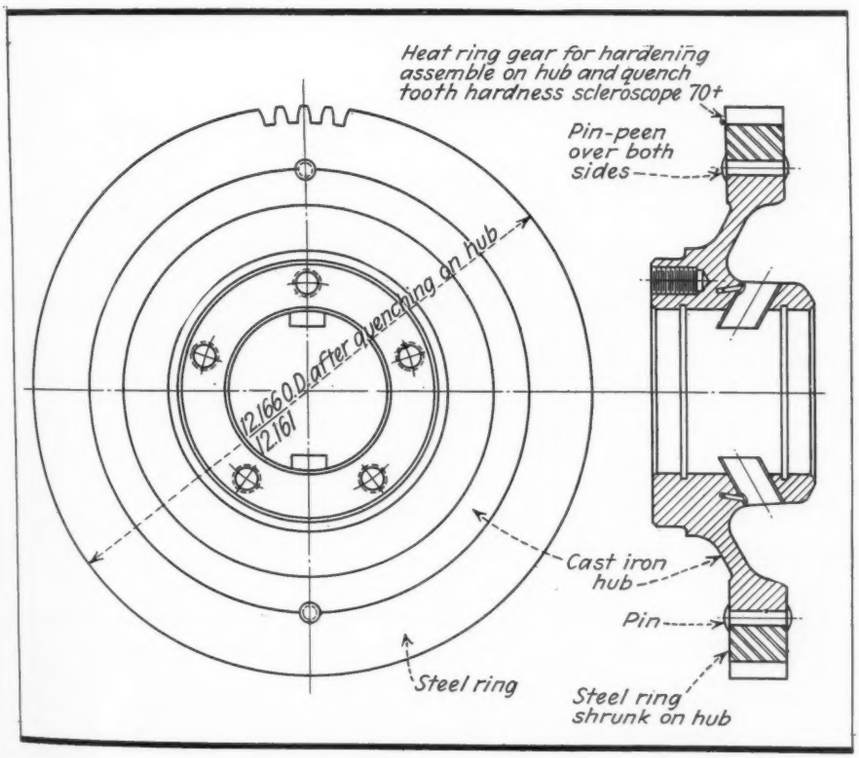
In this underground junction box for a 600 volt main-power line, original design was for cast aluminum using No. 43 alloy, 95 percent aluminum, 5 percent silicon. The walls were 1/4 to 5/16 in. thick to insure no porosity. In production, blow holes or other casting defects sometimes appeared, requiring patching by pre-heating and filling in. This was laborious and costly. Since specifications called for a non-magnetic and corrosion-resistant material, stainless steel, 18–8, of welded construction was adopted. The welding rod is stabilized with columbium. Stainless plate is 1/8 in. thick. The final design weighs about the same as the previous design, but final cost is about 10 percent less. Machining time is reduced, rejects caused by porosity are eliminated, and any leaks that might appear can be easily repaired by welding. No patterns were needed. This design is by G. & W. Electric Specialty Company.

Lowered Cost, Increased Production

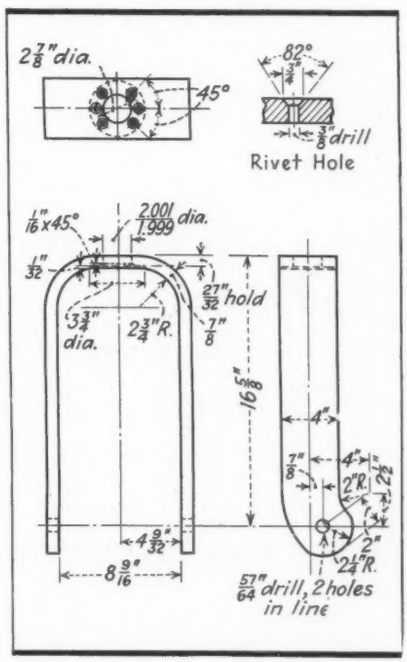
Built-Up, Welded and Flame-Hardened Parts for Heavy-Duty Tractors

Formerly cast, Cleveland tractor drive sprockets are now built-up from S.A.E. 1045 disks and rings, notched, riveted, hobbed and flame-hardened. Each sprocket consists of a formed disk to which two rings are riveted to serve as the rim. The disks are purchased in the form of hot-rolled circular blanks which are perforated and formed, after which they are notched. Notching die is interchangeable for rings and disks, which saves costs and reduces errors. Production of 60 pieces per hour is feasible. Eight sprocket assemblies in one set-up require 2 hours for hobbing. Sixteen sprockets are flame-hardened simultaneously. They are tightly clamped on an arbor to eliminate space between teeth which would cause uneven hardening. Head, designed to fit over tooth contour, moves along work at 7 in. per min. to give depth of hardness penetration from 1/8 to 3/16 in. and hardness of 70 scleroscope.




Heat ring gear for hardening assemble on hub and quench tooth hardness scleroscope 70+
Pin-peen over both sides
12.166 O.D. after quenching on hub
12.161
Cast iron hub
Pin
Steel ring
Steel ring shrunk on hub

Savings in material cost, better physical, machining and hardening properties were obtained in this built-up bull gear for Cleveland tractors, by designing the assembly so that the ring gear, finish-machined and heated to 425 deg. F., is shrunk onto the cast iron hub. Ring gear is a bar of S.A.E. *Y*-1340, rolled up, butt welded, and the teeth machined. After assembly the teeth are flame hardened to 70 scleroscope.



Brake forming of this Cleveland tractor front wheel fork eliminated die costs and forging operations, thus speeding production. For equal strength, half again as much material, S.A.E. 1020 hot-rolled steel, is required for the formed part. But its cost is less, the finished forging costing 10 cents per pound, whereas the formed part costs only 3½ cents per pound.

BRAZED ASSEMBLIES

The designs shown on the following pages demonstrate how brazing . . . . . .

1. Speeds assembly
2. Minimizes machining time
3. Economizes on material
4. Reduces weight
5. Produces dimensionally accurate parts

CONTROLLED ATMOSPHERE BRAZING

Used for brazing assemblies of steel pieces, controlled atmosphere copper brazing has the added advantage that the brazed parts come out of the furnace bright and shiny, the reducing atmosphere deoxidizing the surfaces.

GENERAL RULES FOR THE DESIGN OF PARTS TO BE FURNACE BRAZED

1. FITS. Light pressed fits that will hold the pieces in position as assembled are best.

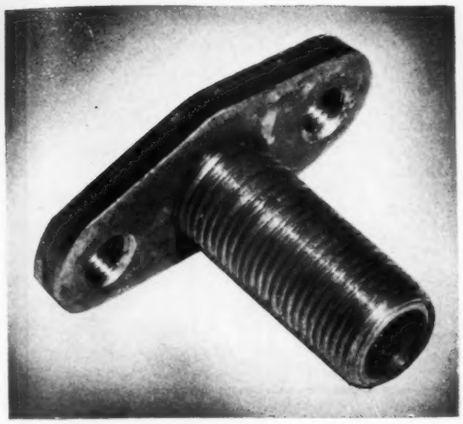
2. FLOW OF BRAZING COPPER. Copper brazing has been known to flow vertically upwards as much as 13 in. against the force of gravity. Excessive clearance, more than 0.005 in. will prevent flowing of the brazing alloy.

STRENGTH OF COPPER BRAZED JOINTS

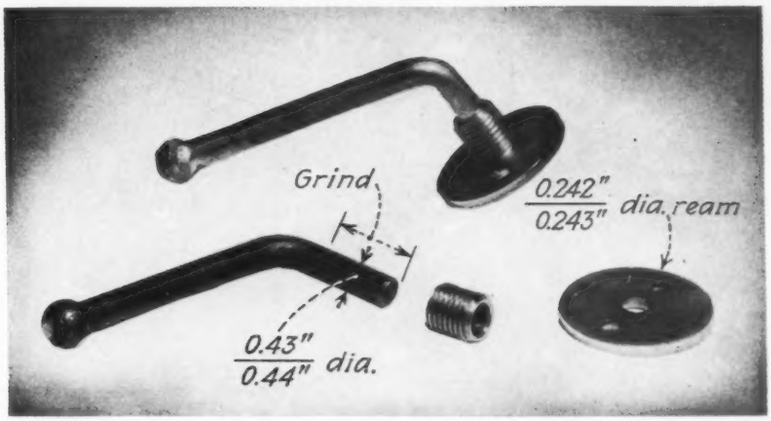
Material	Shear Strength in lb. per sq. in.	
	Clearance 0.003 in.	Tight Press Fit
Mild Steel	22,000	29,000
Alloy Steel	30,000	50,000

For further details on furnace brazing see PRODUCT ENGINEERING, Dec. 1936, p. 441; April 1939, p. 166; August 1939, p. 341.

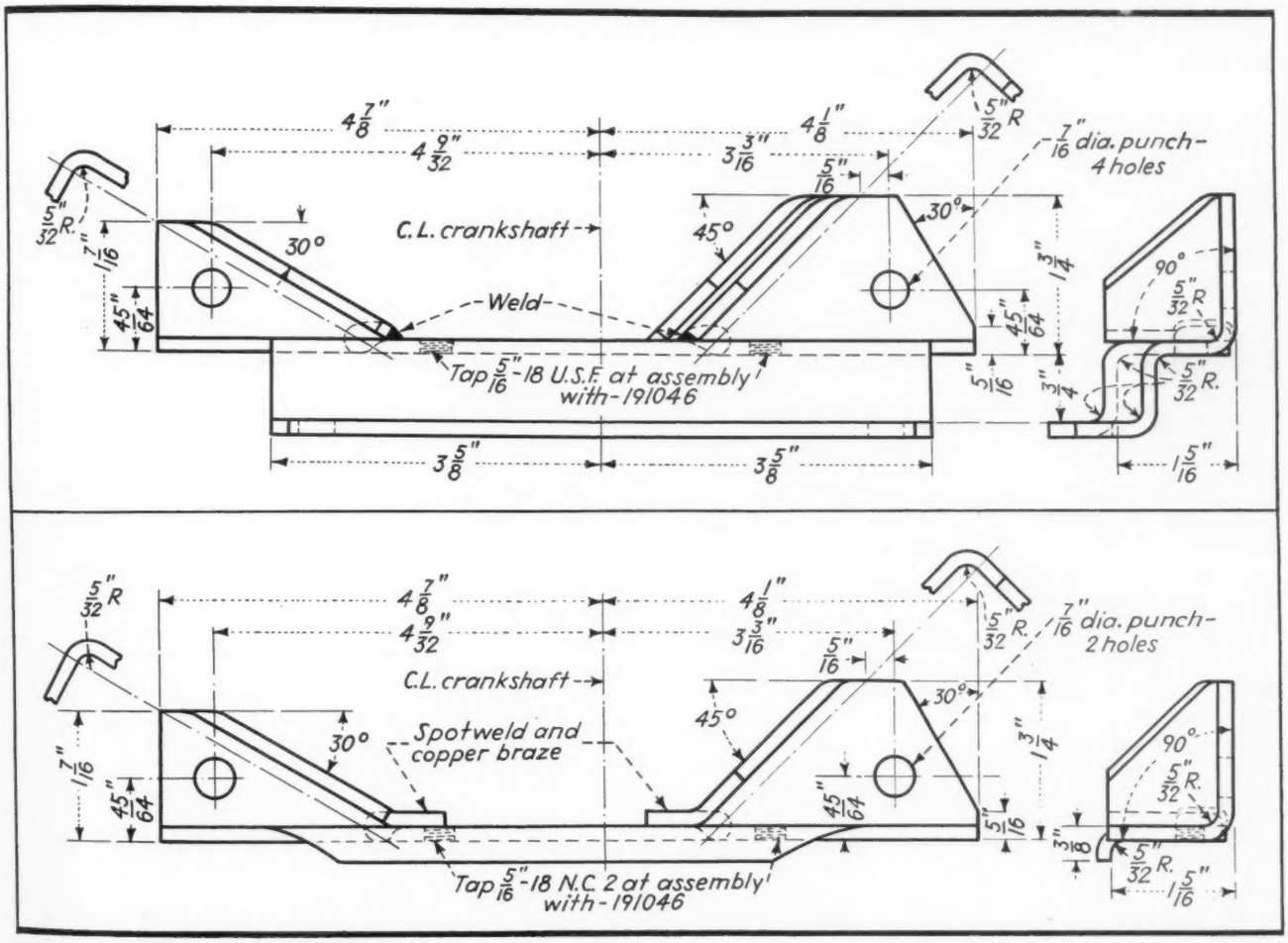
Outstanding Brazed Constructions



Pipe nipple copper brazed to punched flange gives an economical and efficient assembly with the nipple threads continuing to the surface of the flange. Brazing leaves a fillet radius of only a few hundredths of an inch.

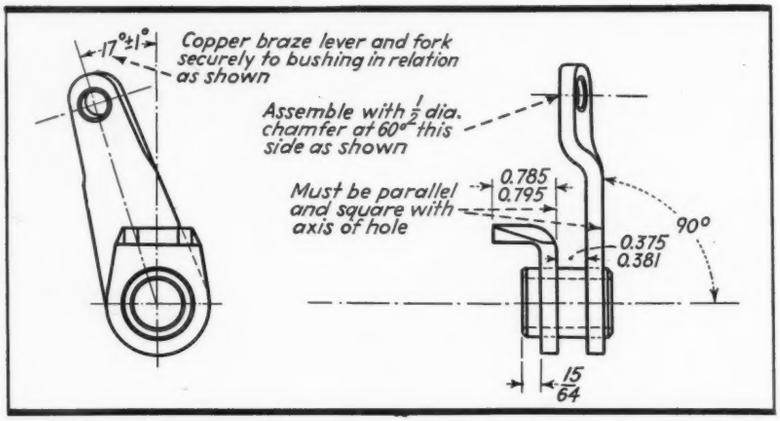


Cowl ventilator control lever for Studebaker cars is a brazed assembly of a threaded collar, cold-rolled steel forged and machined handle and a punched retainer disk. This unit would cost many times more if it were made as an upset forging and machined. The disk is a light press fit on the handle, to hold during brazing.



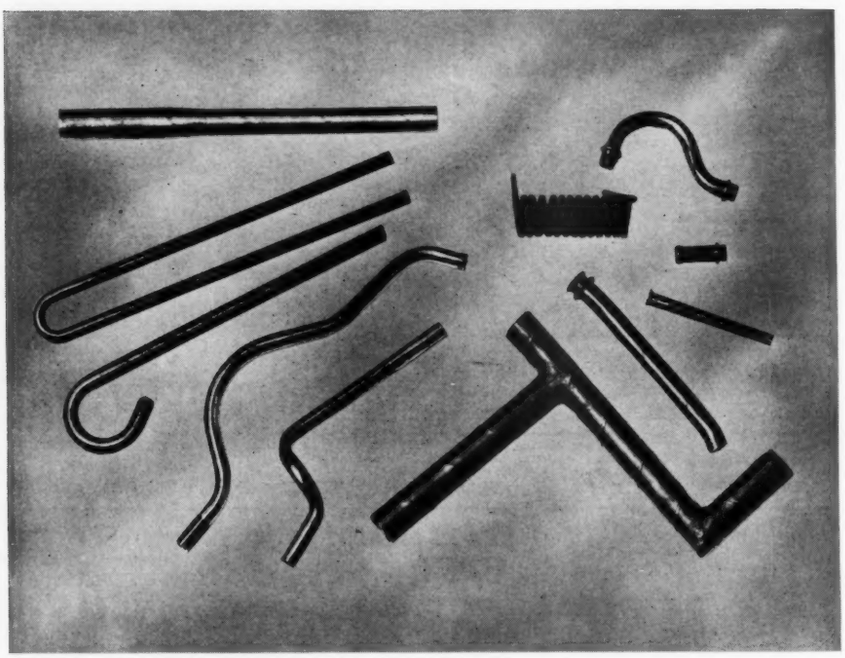
Engine front support brackets—welded design above, brazed design below. Note the spot welds on the brazed unit to hold together the surfaces to be brazed. Welding required that the weld spatter be cleaned off. Brazing requires less labor and the parts come out of the furnace bright. The addition of the "ears" in the brazed design makes it stronger.

(Continued on next page)


17° ± 1°
Copper braze lever and fork securely to bushing in relation as shown
Assemble with 1/2 dia. chamfer at 60° this side as shown
Must be parallel and square with axis of hole
0.785
0.795
90°
0.375
0.381
15/64

Shift lever made by Studebaker as a brazed assembly of two stampings and a bushing. Parts are tight press fits assembled in a fixture, copper wires are put in place and the unit then conveyed through the brazing furnace. Parts come out bright and clean. As indicated, dimensions are held to within 0.01 in. without machining.

Spiral Pressure Brazed Tubing



Constant end pressure is applied to spiralled strip, as the edges are brazed to form continuous tubing in a hydrogen atmosphere high-frequency induction furnace. Because the heating and cooling cycle is short, decarburization is avoided even in high-carbon steels. Rapid heating of the tubing in the brazing operation also prevents harmful grain growth.

Spiral pressure brazed tubing as developed by the AGA Metal Tube Company can be formed from cold rolled strip S.A.E. 1010 low carbon, high carbon, chrome molybdenum S.A.E. 4130X and the 4150 steels, as well as Monel.

The tubing is produced in tempers ranging from hard drawn, half hard, quarter hard and dead soft to make available properties as required in fabricating operations such as machining, bending, coiling, forming, flanging and cold drawing. The tubing is as strong as the parent metal. Annealed tubing made from S.A.E. 1010 low-carbon steel has a yield point of 27,000 to 30,000 lb. per sq. in., a tensile strength of 47,000 to 50,000 lb. per sq. in., an elongation in 2 in. of 38 to 42 percent, and a reduction in area of 60 to 68 percent.

Maximum Working Pressures for Spiral Pressure Brazed Tubing

Outside dia., in.	Wall thickness in.	Hydraulic pressure lb. per sq. in.
1/8	0.022	6,000
3/16	0.022	4,400
3/16	0.028	5,500
1/4	0.028	4,200
1/4	0.032	4,700
5/16	0.028	3,500
5/16	0.032	3,800
5/16	0.035	4,200
5/16	0.042	5,000
3/8	0.028	2,900
3/8	0.032	3,300
3/8	0.035	3,750
3/8	0.042	4,150
7/16	0.032	2,800
1/2	0.035	2,700
5/8	0.035	2,250

Hard drawn S.A.E. 1010 low-carbon spiral brazed tubing has a tensile strength of 80,000 to 85,000 lb. per sq. in., and is recommended for straight parts requiring strength and machining qualities.

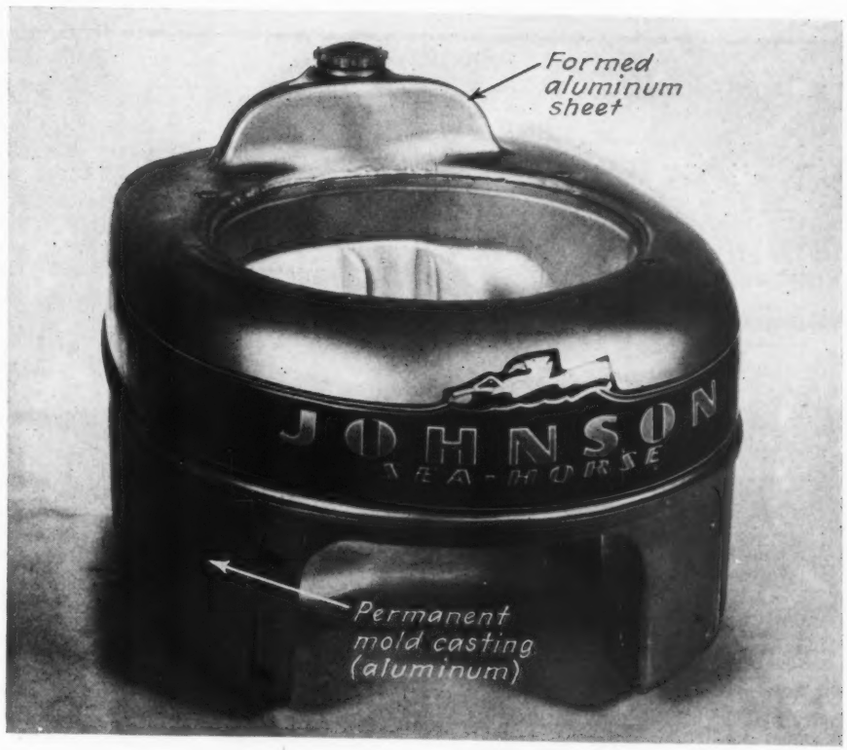
Spiral pressure brazed tubing is available in lengths up to 40 ft. in sizes ranging from 1/8 to 5/8 in. O.D. Wall thickness ranges from 0.010 to 0.049 in. in the smaller sizes, and from 0.020 to 0.042 in. in the larger sizes. Tolerances are ± 0.002 in. Since the tubing is drawn over a mandrel the wall thickness is uniform and the interior smooth.

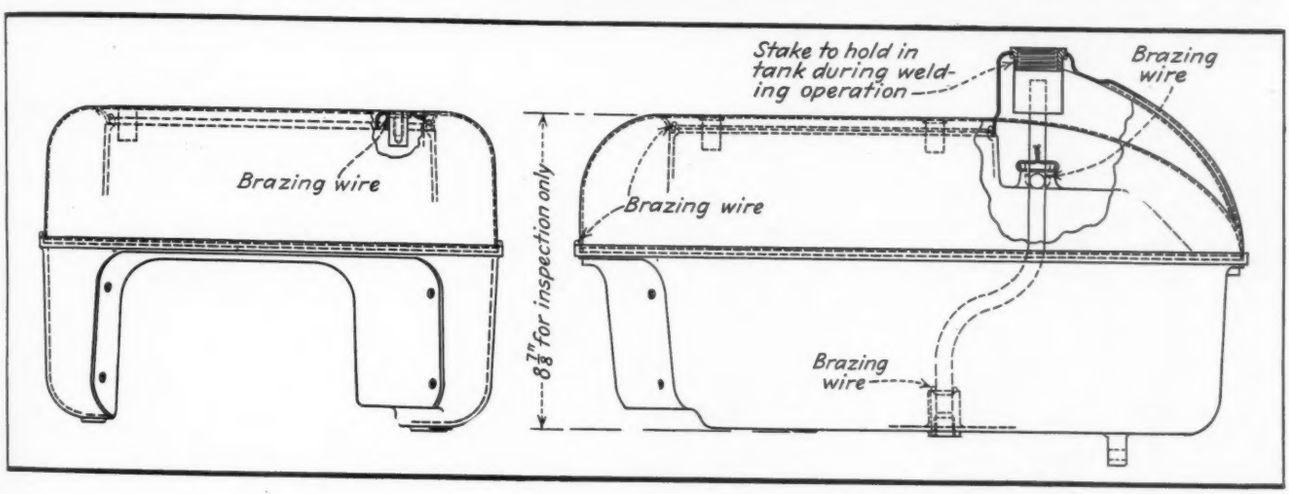
Stampings and Castings Brazed

Smaller size tanks for Johnson outboard motors are two aluminum stampings brazed together. P.E., page 176, April 1940. Larger capacity tanks serve also as a motor shroud, requiring a bottom part too deep to be made as a stamping and hence made as a permanent mold aluminum casting.

Assembly is in two brazing operations. First, all fittings for stamped upper part are staked in place, the sheet is fluxed, brazing wires are put in place and the part then put through the brazing furnace. After that the coverplate brazed assembly is placed on the permanent mold casting, the surfaces are fluxed, brazing wire is placed as indicated in the drawing and the assembly is put through the brazing furnace. For the second brazing operation the brazing wire used melts at a temperature lower than the melting temperature of the wire used in the first brazing.

The alloy for the permanent mold casting must be held to a close analysis—5 percent silicon, balance aluminum. This gives the highest possible melting temperature for cast aluminum.



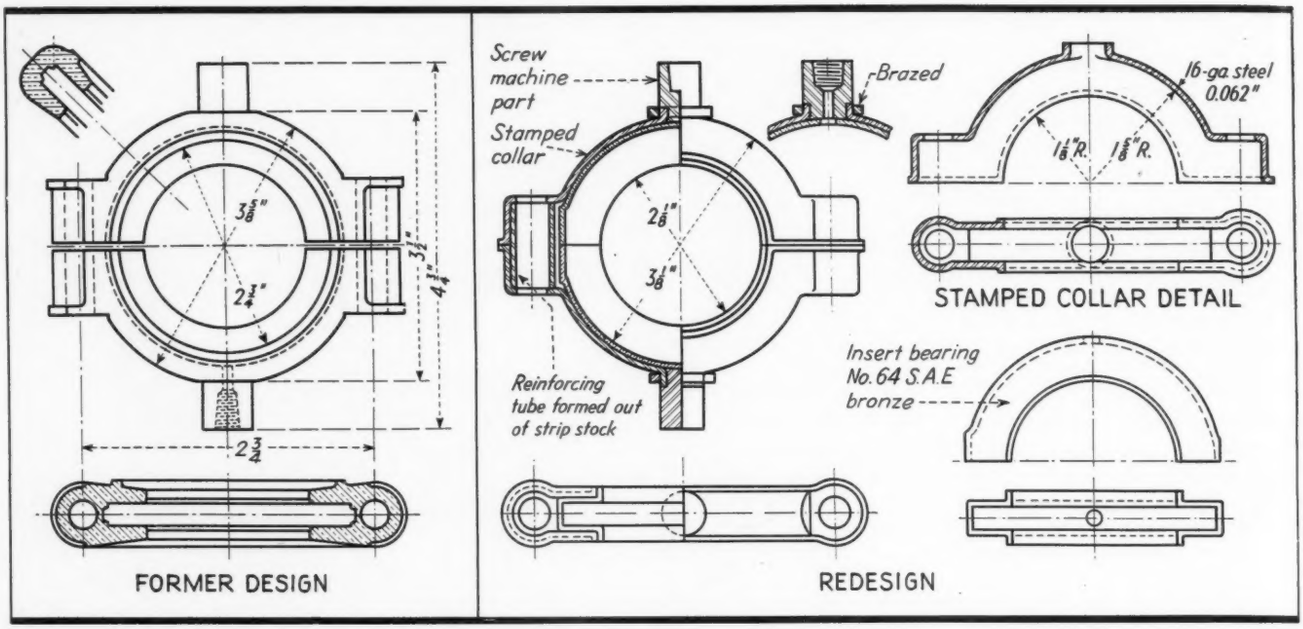


Furnace Brazing Characteristics of Aluminum Alloys

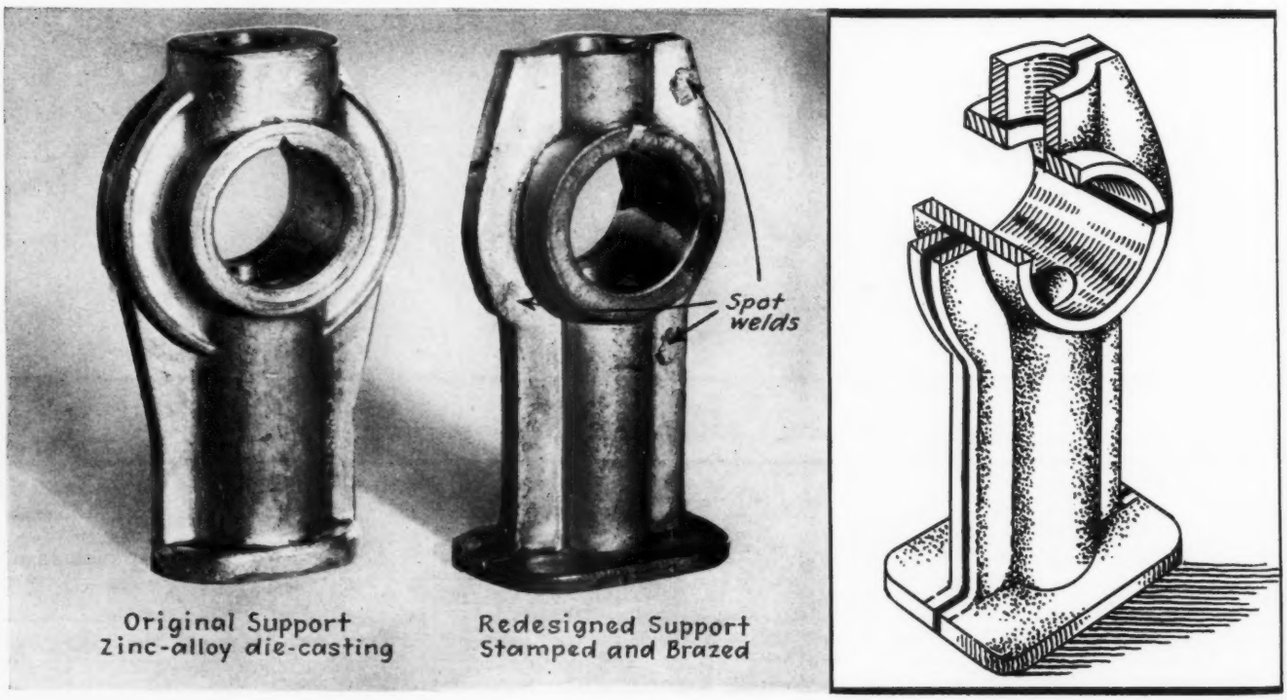
	Wrought Alloys							Casting Alloys				
	Non-heat-treatable			Heat-treatable				Non-heat-treatable				Heat-treatable
	2S	3S	52S	53S	61S	Alco. 17S	Alco. 24S	43	214	B214	406	356
1. Brazability	Good	Good	Poor	Fair	Good	Poor	Poor	Fair	Poor	Poor	Good	Poor
2. Filler material	13S	43S	..	X-716	X-716	....	....	X-716	..	..	43S	....
3. Flux	30	30	..	33	33	....	....	33	..	..	30	....
4. Brazing temperature deg. F	1160 1185	1160 1185	.. ..	1065 1090	1065 1090	....	....	1040 1050	.. ..	.. ..	1160 1185	....

Notes: Thickness range for alloys listed is 0.006 to ½ in. For examples of typical brazed joints see P.E., April 1940, p. 176.

Brazed Parts Replace Castings



In former design, thrust collar was machined from a 64 S.A.E. bronze casting and then split across the bolt lugs. The total weight of the bronze collar casting was 1.77 lb. In the new design of thrust collars for Twin Disc clutches, tubes, stampings and screw machine parts are assembled by hydrogen brazing. Total weight of bronze in the new thrust collars is 4.5 oz. each—a saving of 1.5 lb. per unit. The design was a joint development of Fred Adamson, chief engineer of Twin Disc, and the engineers of Toledo Stamping and Manufacturing Company.

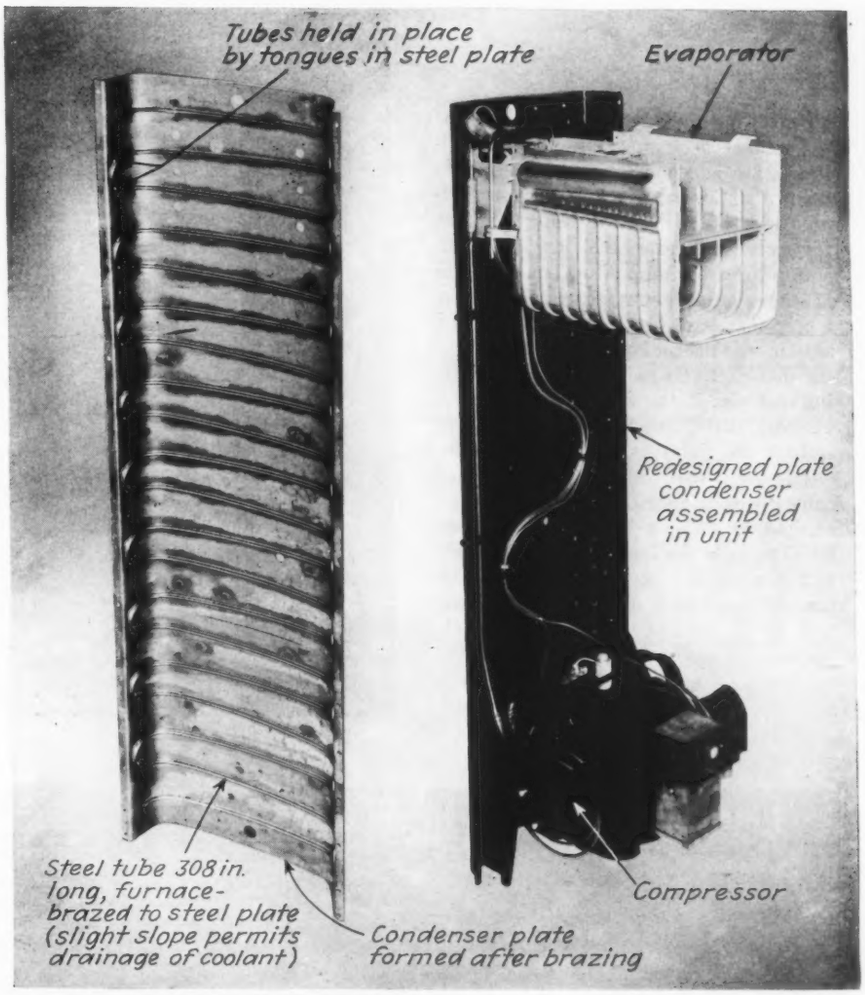


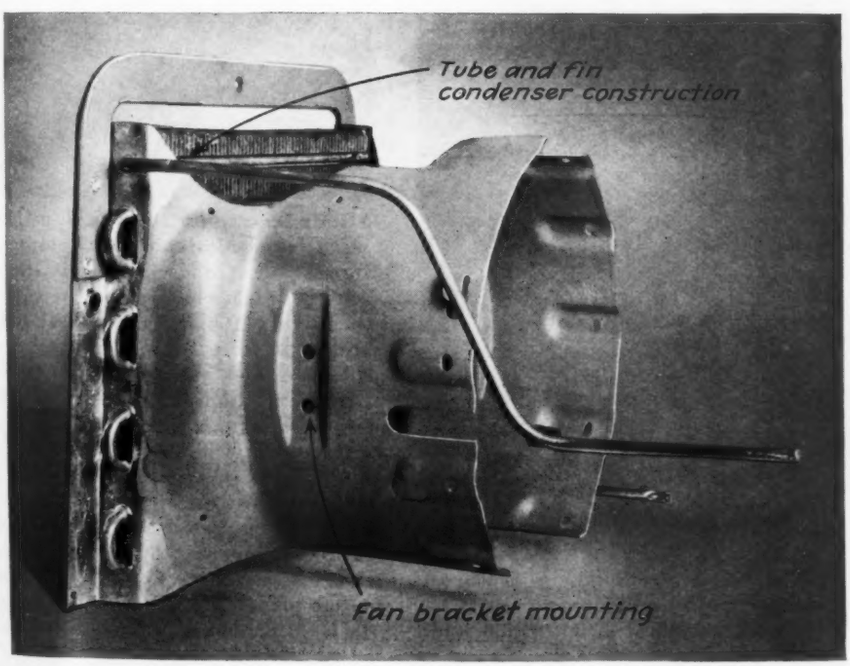
Rocker arm support for tractor engines of Allis-Chalmers Manufacturing Company was originally designed as a zinc alloy die-casting. In service, the effects of time, load and temperature caused the supports to lose their strength in compression. The part was then redesigned as a furnace-brazed support, shown at right. Three stampings are assembled by spot-welding. After applying brazing wire to the welded unit, it is passed through a controlled-atmosphere electric brazing furnace. Analysis showed cost to be 15 percent below that for die-casting.

Brazing Simplifies Condenser

New plate type condenser for Westinghouse domestic refrigerator unit is much simpler to fabricate by furnace brazing than is the former tube and fin type condenser. For the new design, a steel tube 25 ft. 8 in. long is first shaped to a grid form with hair-pin bends in a flat plane. The formed tube is then placed on a flat steel backing plate and fastened in place under tongue snaps stamped in the plate. Copper brazing wire is then placed alongside the condenser tube where it makes contact with the plate. In the next operation the tube and plate assembly, carried on a conveyor, are brazed in a furnace. After brazing the rupture strength of the bond exceeds 8,000 lb. per sq. in. The brazed plate and tube unit is then formed into a shallow channel shaped panel.

This type of construction provides a homogeneous bond for heat transfer. A regulated distribution of the refrigerant is also obtained with a consequent control of the temperature at all zones in the condenser. The result is an absence of hot and cold areas in the condenser during operation. The straight legs in the tube of the assembled unit are inclined slightly from the horizontal, to obtain gravity drainage of the condensate and to prevent trapping of the liquid.


Tubes held in place by tongues in steel plate
Evaporator
Redesigned plate condenser assembled in unit
Steel tube 308 in. long, furnace-brazed to steel plate (slight slope permits drainage of coolant)
Condenser plate formed after brazing
Compressor

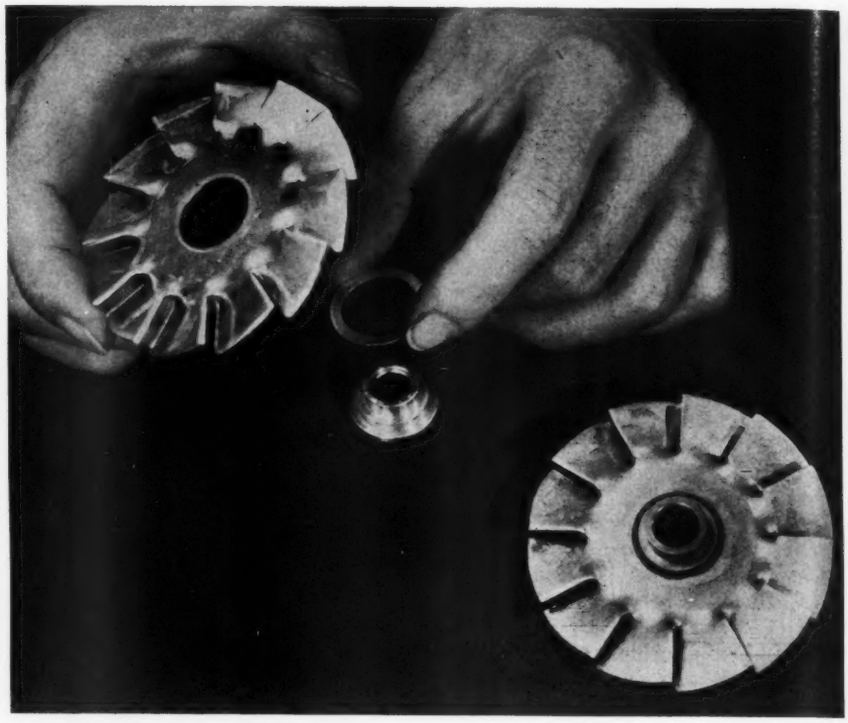


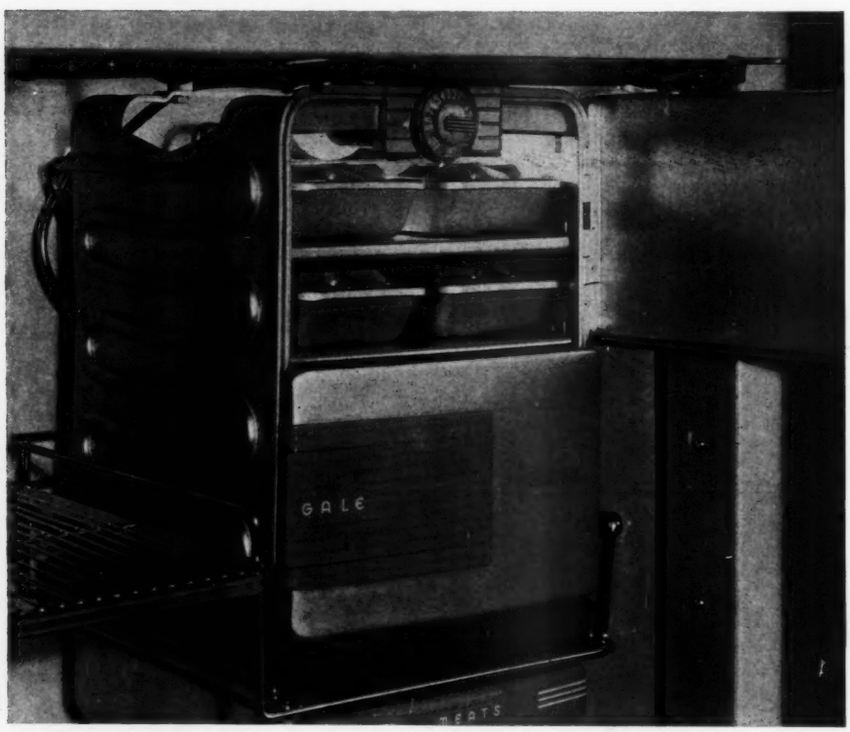
Previous domestic refrigerator condenser was a complicated and expensive construction with the condenser tube fitted into notched fins. In this design were incorporated a hanger stirrup and parts of stamped and formed sheets for attachment to other units. In earlier designs, plate condensers were made by resistance welding two sheets together, with a condensing space between. These designs, however, had the disadvantage of greater hazard from dirt, leaks and uncertain strength.

ELECTRIC FURNACE BRAZING can be used to improve the quality and to reduce the costs of many non-ferrous parts. To obtain effective results, it is important to consider the fusibility between the metals joined and the brazing alloy when selecting the brazing alloy and in determining the operating temperature.

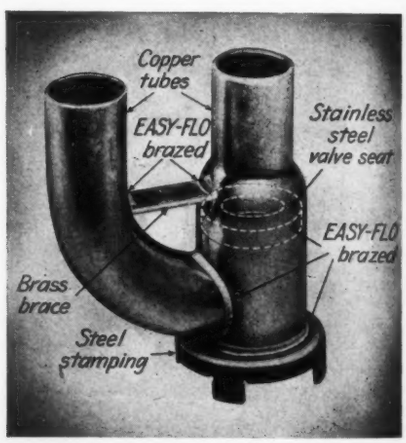
Furnace Brazing Facilitates Assembly

Furnace brazing as a method for assembling a stamped aluminum ventilating fan and a machined hub, speeds up production of Black & Decker portable electric tools. The same die that formerly stamped a steel fan is used to stamp the aluminum alloy fan. Die life is longer on aluminum parts. Hub, formerly made of steel, is now made of aluminum thus reducing machining time for this part. By using aluminum brazing material in the form of a washer, a uniform distribution of brazing material at the joint is obtained, thereby eliminating one of the factors that caused unbalance with the former method of using a bronze brazing material to form the bond between the hub and fan. The light weight aluminum fan also reduced the balancing problem.





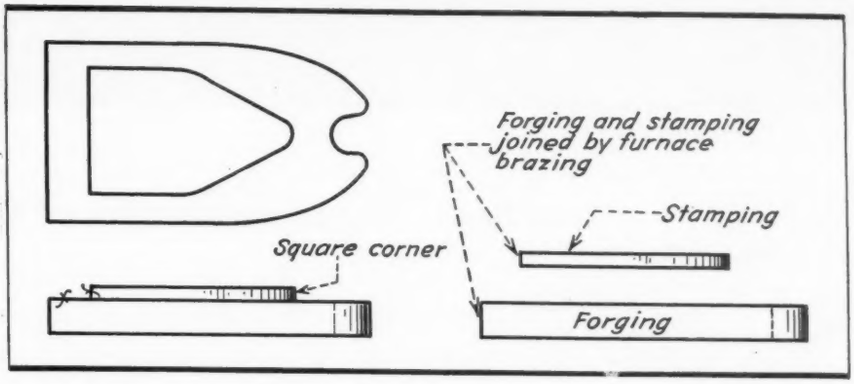
Aluminum evaporator unit assembly is simplified by furnace brazing, with consequent speeding up of production and reduction in costs. Aluminum tubing and extruded molding are brazed to an aluminum shell to make a one piece unit. Tubing and molding are first brazed to flat sheet which is then bent to the shape of evaporator. The neat joint between the tubing and shell, on the exterior wall of the evaporator unit adds to the appearance value.

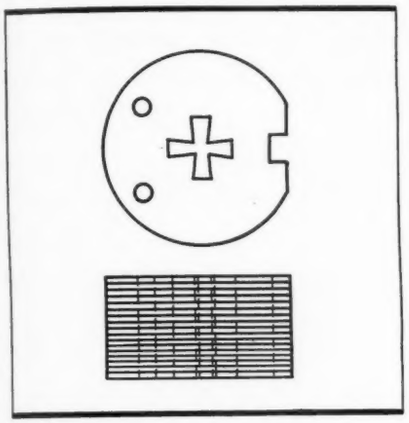


Silver brazing alloys make possible rapid, economical production of parts formerly cast and machined. Heater valve body made of two pieces of copper tubing with 20 B.&S. gage walls, a brass bridge piece, a steel stamping and a stainless steel valve seat. Parts are assembled, aligned and fluxed, then rings of Easy-Flo silver brazing alloy wire are placed around joints, after which the assembly is furnace-brazed in one operation. Medium silver content brazing alloy flows freely at 1,175 deg. F. In addition to eliminating casting and machining operations, dissimilar metals copper, brass, steel and stainless steel are permanently bonded together with leak-tight joints.

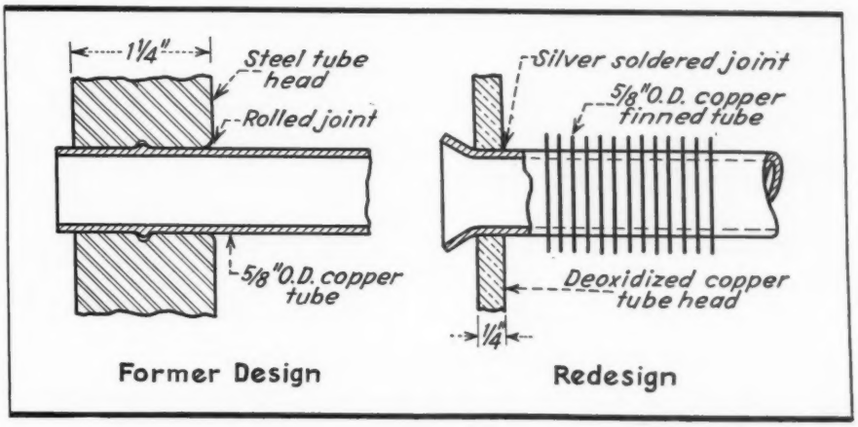
Brazed Assemblies of Proved Economy

Diagrammatic illustration of a part originally made as a single forging. Surfaces had to be machined in order to obtain a sharp, square corner, as indicated. In redesign, the part was made in two pieces, a forging and a stamping, and the two pieces furnace brazed. All machining operations were eliminated with the brazed design.

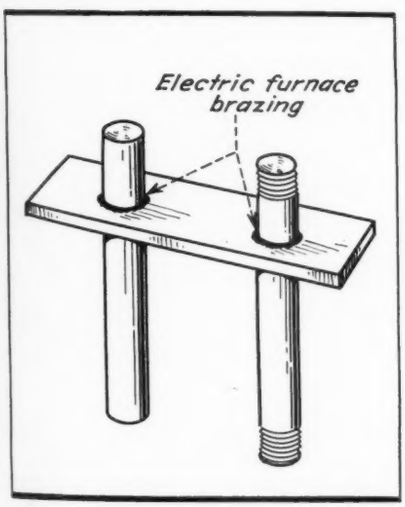




Irregular shapes of uniform cross-section can be made economically by punching out laminations, stacking them and brazing in a furnace. Made of copper-coated sheet steel, the copper coating serves as the brazing metal. This construction was developed at Westinghouse originally for making stripper plates for punches and dies.



In assembling tubes to the header sheet, the old practice was to drill, ream and groove tube holes in steel tube heads 1¼ in. thick, insert the tube end and roll the joint leak tight. In York Ice Machinery Corporation's new design, to make possible the use of relatively thin deoxidized copper sheet for the tube head, the copper finned tubes are silver soldered to the copper tube head, making a strong bond. With this design, copper tube head is only ¼ in. thick, saving much material; man-hours required were reduced 20 percent.



An assembly of pins in a steel plate was formerly made by Westinghouse Electric & Mfg. Company with a silver solder joint. The electric furnace brazing method now used increases the strength and also makes a substantial cost reduction.

Furnace Brazing Data

BRAZING METAL—For steel parts, copper or brass in the form of wire, paste or powder. For inaccessible surfaces, use copper-coated steel or make a spray consisting of copper or brass powder mixed with lacquer, and thin. This mixture is sprayed or brushed on the surfaces to be brazed.

For aluminum, a special flux and brazing metal is required. For inaccessible places, the aluminum sheet can be obtained with the brazing material rolled in along the edges.

FURNACE TEMPERATURE—For brass wire or powder, 1,740 to 2,000 deg. F.; for copper brazing, about 2,100 deg. F. Furnace temperature can be anything reasonably higher that will not be detrimental to the parts.

FURNACE ATMOSPHERE—Percent composition CO_2—5.6; H_2—11.9; CO—10.3; CH_4—0.2; N_2—72.0. No oxygen.

Heating for annealing or hardening can be simultaneous with the furnace brazing. All heating operations subsequent to the furnace brazing must be at temperatures below those given above, that is, below the melting temperatures of the brazing metal used.

FIT OF PART—Light press fits are desirable. Tight fits increase the flow of the brazing material into the joint, the tighter the joint the farther the molten metal will flow. Void spots or gaps are difficult to seal because clearance is too great to permit capillary attraction drawing the molten metal into the joints.

FORMED PARTS

ECONOMICAL PRODUCTION FEATURES OF FORMED PARTS

Sand Castings

Complex shapes might be split into components of simple castings or simple castings can be combined with forgings or structural steel parts—the components being assembled by fusion or resistance welding.

Permanent Mold Castings

Mostly confined to aluminum, zinc, brass and low melting alloys, sometimes cast iron. Changing from sand castings to permanent mold castings often, with judicious designing, eliminates much machining because casting tolerances are small.

Die Casting

Usually zinc, aluminum, brass, bronze, or magnesium. Little machining required. Cast-in inserts save assembly time and fastenings.

Centrifugal Castings

Practically all metals, most commonly cast iron and aluminum bronzes. Featured by extremely dense metal and small allowances for finishing because casting tolerances are small.

Forgings

Die costs can often be greatly reduced by making simple parts to be joined by welding, instead of a single complicated forging. Dimensions can be made closer than the commercial tolerances given on page 190 by the addition of coining operations.

Powdered Metal Pressings

Aluminum, cast iron, bronze. Other metals still in experimental stage. Featured by controllable density or porosity, highest dimensional accuracy, smoothest surface finish with strength as high as 80 per cent of that of the virgin solid metal.

Stampings

Brazed or welded assemblies of stampings and stampings with screw machine parts, castings, or forgings offer many possibilities.

Metal Spinnings

An all too-little used method of metal forming, the possible economies of which have been greatly extended by brazing and welding.

Sand Castings

For detailed design data including shrinkage allowances, machined finish allowances, dimensional tolerances, draft angles and minimum section thicknesses for steel, iron and non-ferrous castings, see *Cast Metals Handbook*, American Foundrymen's Association, 222 West Adams Street, Chicago, Ill.

Centrifugal Casting

MATERIALS SUITABLE
Aluminum, bronze, monel, beryllium copper, iron, steels of various grades, stainless steel, copper and other non-ferrous materials.

SHAPES
Any combinations of cylindrical shapes such as wheels, gears, screw-down nuts, bushings with tapers and parts with varying diameters.

MAXIMUM SIZE
Screw-down nuts, weighing approximately 3,600 lb. each, for a new continuous-type steel mill, have been centrifugally cast.

FINISH ALLOWANCES

Outside Dia.	*O.D. Allowance*	*I.D. Allowance*
2 in. or less...	1/8 in.	1/8 in.
2 to 4 1/2 in...	1/4 in.	1/8 in.
4 1/2 to 6 in...	5/16 in.	1/8 in.
6 to 10 in...	3/8 in.	1/4 in.
Over 10 in.....	1/2 in.	1/4 in.

Ford casting of both bevel and cluster gear blanks allows only 1/32 to 1/16 in. stock for machining.

WALL THICKNESS
Practical minimum about 1/4 in.

RELATIVE COST
More costly in small quantities than sand castings in small quantities. However as quantity increases to 20 or more, the cost is little if any more because of the material required for extra gates and risers in sand castings. Centrifugal mold cost is only about 15 percent that of a comparable forging die. Generally the cost of a permanent metal die for centrifugal casting can be justified by as few as 10 or 12 pieces although customarily such a die is not made for fewer than 25 or 30 pieces.

TYPICAL EXAMPLES
The bushings for Hamilton Standard propellers were formerly sand cast of beryllium copper with scrap running as high as 30 percent. Permanent mold castings did not prove feasible. Scrap has been almost eliminated by use of aluminum bronze centrifugal castings of tapered hollow bushings.

In another case several hundred bronze rings, about 45 in. O.D., and 20 in. I.D. and 3 in. thick, originally specified as forgings were found to have satisfactory physical properties when centrifugally cast. Die costs would have been high for the comparatively few forgings required. Another gain was less time required to get delivery.

Permanent Mold Casting

SIZE LIMITATIONS
Largest permanent mold casting produced, 20x16x34 in., weighing more than 100 pounds.

Smallest permanent mold casting produced weighed less than one ounce.

MINIMUM TOLERANCE, ALL DIMENSIONS
Up to 5 inches.....±0.010 in.
Over 5 inches.....add 0.001 in. per in. of length

UNDERCUTS
Omit wherever possible, but if unavoidable they can be produced through use of collapsible metal core or, if impractical, by use of baked sand core.

SECTION THICKNESS, minimum.....0.085 in.
CORED HOLES, minimum diameter.....0.25 in.
DRAFT ANGLE, minimum.....0.5 deg. per side
INSERTS—Steel or cast iron inserts practical
CAST THREADS—Not practical

Aluminum Die Casting

SIZE LIMITATIONS
Maximum practical overall dimensions.....36x12x9 in.
(Few aluminum die castings exceed 25 in. in length)
Largest produced—In size.....84x12x1 in. (14 lb.)
(Die-cast dog used as trade mark on Greyhound buses)
By weight.....19 lb. (12x19x20 in.)
(Die-cast cases for Leeds and Northrup instruments)

SECTION THICKNESS
Large castings, minimum.....0.085 to 0.10 in.
Small castings less than 6 in. length or width.....0.050 to 0.065 in.
Avoid abrupt changes in wall thickness

DIMENSIONAL TOLERANCES
In any one dimension.....±0.0015 in. per in.
(Frequently less by trial and error)
Perpendicular to parting line—large castings.....—0.00 to +0.010 in.
small castings.....—0.00 to +0.003 in.
Between points formed by removable part and die, tolerances are the same as those across parting line.

CORED HOLES
Minimum diameter of cored holes.....0.090 in. approx.
Length limit for through holes and blind holes:

Diameter	*Length Limit*	*Diameter*	*Length Limit*
Under 3/16 in.	3 diameters	Over 1/2 in.	10 diameters
To 1/2 in.	6 diameters	Larger holes	No limit

Tolerances on through holes—small holes.....0.001 in.
Closer tolerances on through holes must be obtained by reaming, the hole being cast 0.005 to 0.010 in. undersize
Cores for internal threads—preferable to use threaded insert

DRAFT ALLOWANCES
Outside walls, recommended.....0.010 in./in.
Rectangular core, on each side.....0.008 in./in.
Internal cores, in general, as in table below:

Approx. diameter of hole	*Amount of Draft*
Less than 1/8 in.....	0.015–0.020 in. on dia.
1/8 to 1 in.....	0.010–0.015 in. on dia.
More than 1 in.....	0.010–0.030 in. on dia. (depending on size and design)

If no draft is permissible ream or, unless hole is shallow, use insert.
Small holes for tapping usually cast to root diameter of thread plus 15 percent with standard draft added

INSERTS
If strained, should be knurled on surfaces within casting.
Small pins, if subject to pull, should be both knurled and grooved.

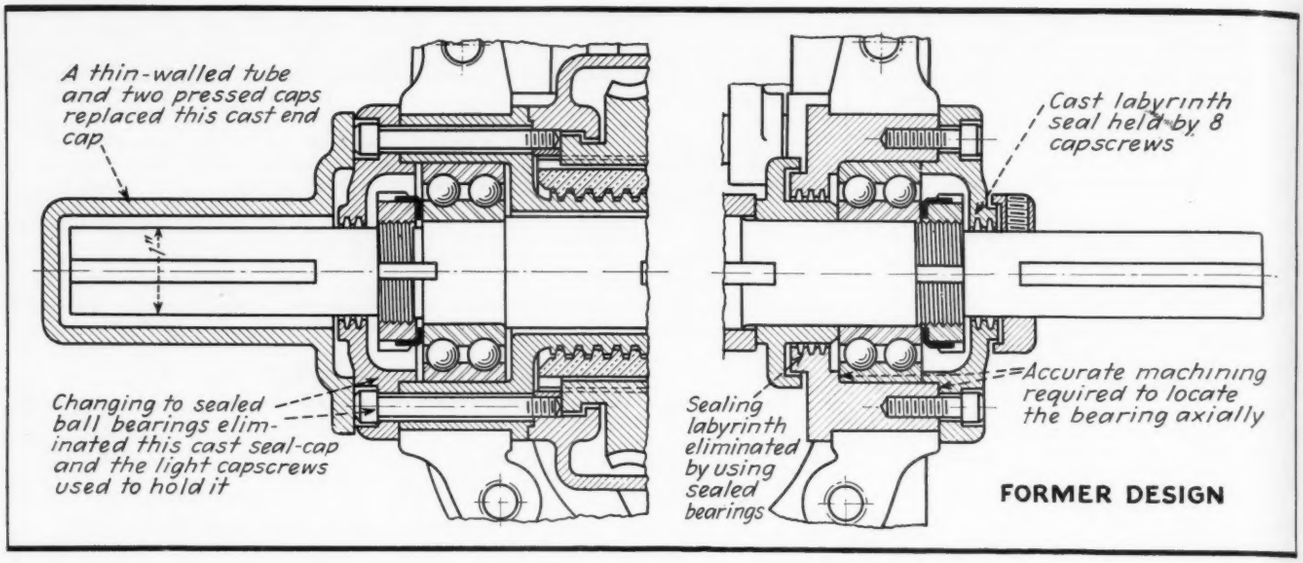
FILLETS
Avoid sharp corners if possible.

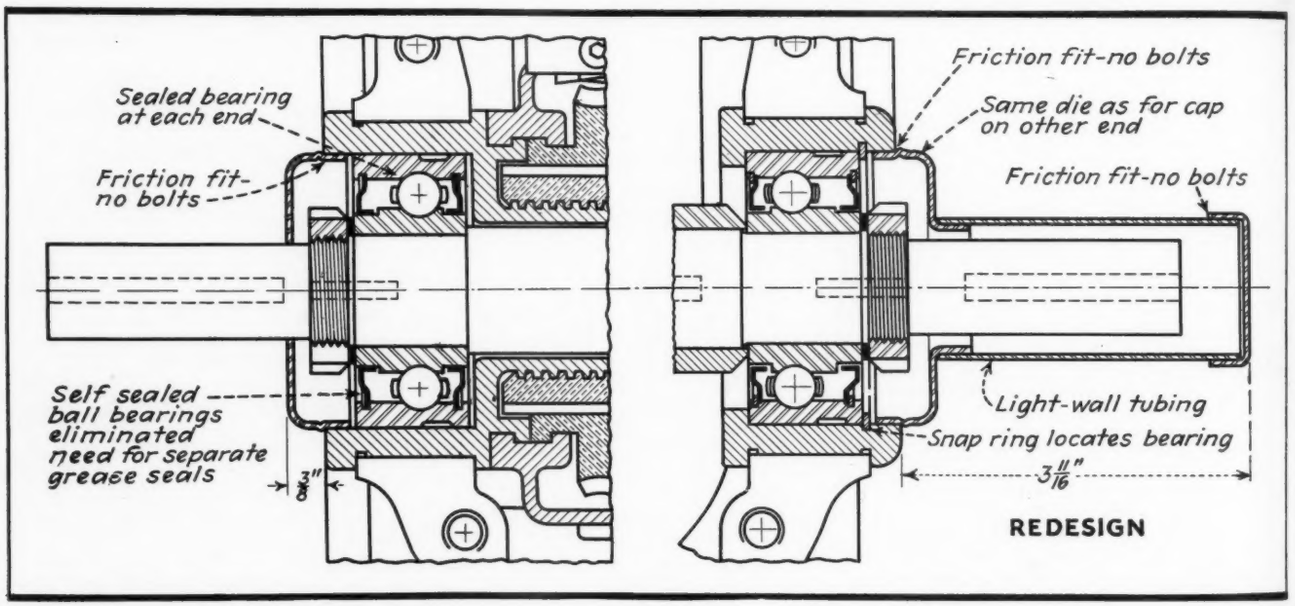
FINISHES
Alumilite finish best on Alloy 218. Colored alumilite best in darker shades. May be plated with common plating metals if desired.

DESIGN TO AID TRIMMING
Design part so that flashes will be in or parallel to main parting plane.

CAST THREADS
Internal threads—best to cast threaded insert
External threads—can be cast and need only light chasing to finish

Stampings in Place of Castings


A thin-walled tube and two pressed caps replaced this cast end cap
Changing to sealed ball bearings eliminated this cast seal-cap and the light capscrews used to hold it
Cast labyrinth seal held by 8 capscrews
Accurate machining required to locate the bearing axially
Sealing labyrinth eliminated by using sealed bearings
FORMER DESIGN



Three stampings, a piece of light-wall tubing, a snap ring, and the use of self-sealed ball bearings, eliminated four castings and 16 cap bolts with all the machining that those parts required. New design also greatly simplifies inspection and servicing of this Allis-Chalmers Vari-Pitch speed changer. Note that the two cups are made on the same die. The bottom of the one cup is then punched to give the opening for the shaft while the other cup has a hole punched in the bottom and "flued" to provide the flange for holding the tube. Caps are interchangeable, either end of shaft can be exposed to permit mounting a sheave.

Centrifugal Castings

Stainless steel separator parts, formerly made from forgings, are now centrifugally cast. With centrifugal casting a fine grain structure is obtained in 18–8 stainless steel. Castings can be machined readily.

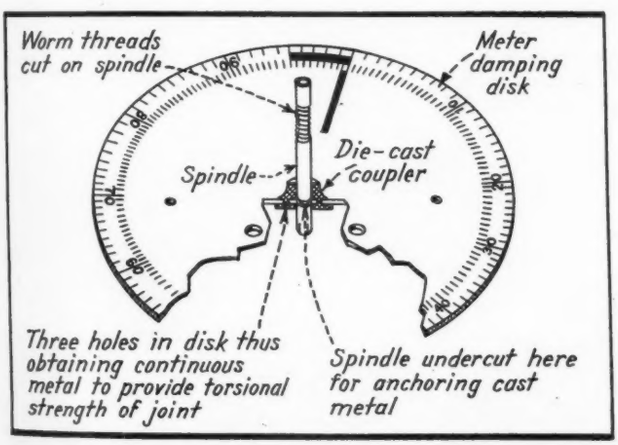
Cast or forged Inconel (80 nickel—12 chrome iron) has been found to give long life for molds for centrifugal castings. Two important factors to be considered in centrifugal casting are the expansion and the heat checking of the molds. In one instance more than 900 parts were cast before the Inconel molds heat checked.

Precision Castings

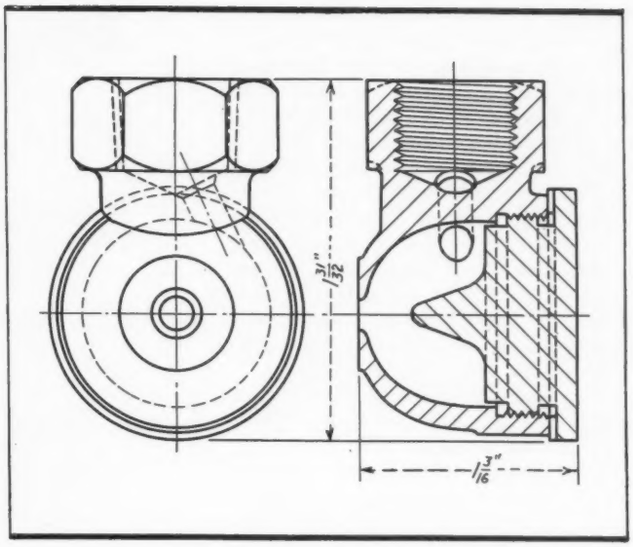
Cleaning operations on large castings, made by the Farrel-Birmingham Company using the Randupson process, are substantially simplified because the sand peels from the castings. Also the absence of gas forming elements in the mold eliminates many small gas scars and blemishes on the surface of the casting. The strength of the cement molds also minimizes warping of the casting and improves its dimensional accuracy generally, thereby reducing the amount of metal ordinarily provided at surfaces that are to be machined to a required finish.

Die-Castings Reduce Cost

Aluminum alloy die-casting for cylinder block of Johnson outboard motor has steel cylinder liners anchored in place when casting. Liners are inserted in die and the metal is cast around them. Intricate cores are used to form passages for cooling water and to reduce weight. As can be seen in the sectional view, pockets for the crankshaft bearings are integral with the die-casting. With this design, many machining and assembling operations have been eliminated. The saving in weight was also considerable. The gas tank for this engine is described on page 173 of this issue.

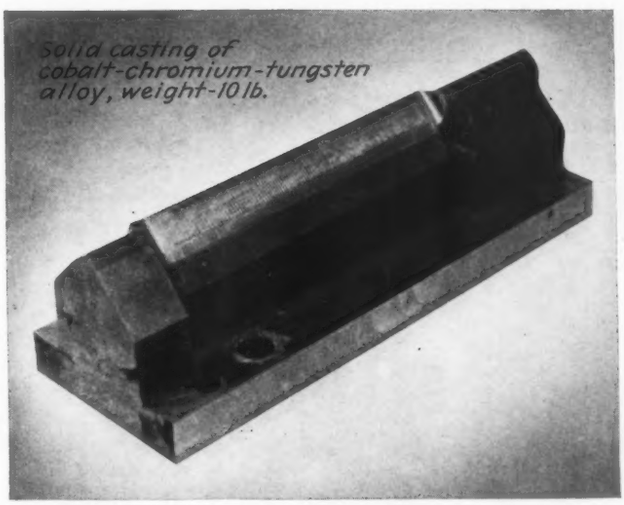

Worm threads cut on spindle
Meter damping disk
Die-cast coupler
Spindle
Three holes in disk thus obtaining continuous metal to provide torsional strength of joint
Spindle undercut here for anchoring cast metal

Zinc alloy die-casting used by Sangamo Electric Company as a quick method of assembling small parts which are difficult to handle in production by other methods. The shaft for the damping disk of a meter formerly was held by two setscrews in a collar made in a screw machine, the collar being staked to the disk. Now the disk and spindle are placed in a die and the collar is die-cast as shown in the illustration. Not only has production time been lowered but the casting die holds the shaft true. Previously, careful inspection and adjustment was often required to insure a true running disk.



Air washer centrifugal spray nozzles are now made by the York Ice Machinery Corporation from bronze die-castings in place of sand castings. Production costs are not only less for the quantities used, but a better unit is also obtained.

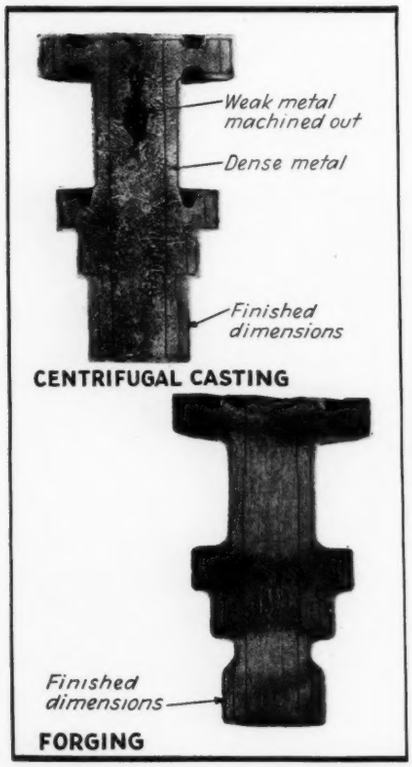
Hard Alloy Castings



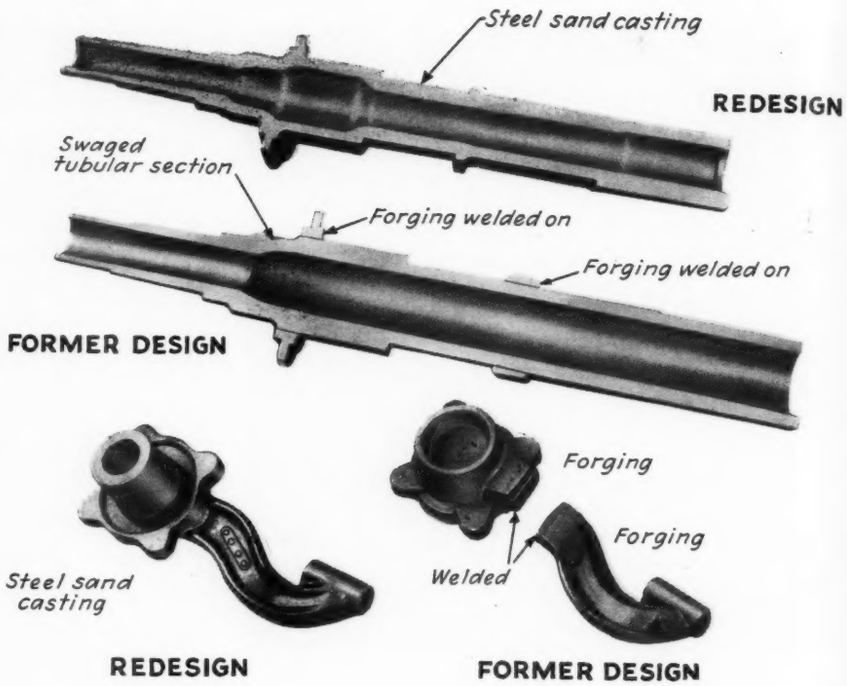
Solid castings of cobalt-chromium-tungsten alloy are more economical, for some punches and dies, than are hard-faced steel parts. Although the initial cost is high as compared to steel, the difference in price is more than offset by longer life. The greater hardness possessed by castings of these alloys when compared with that of the hardest standard grade of hard-facing alloys in the as-welded condition, is an added advantage. The wearing surface of solid cast parts also has a backing which will not mushroom under impact as might a steel base. Although the alloys are finished by grinding, they often can be cast to such close tolerances that finishing is not necessary, thus eliminating machining costs.

Automotive Steel Castings

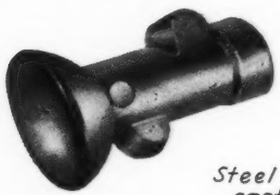
Reductions in unit cost, stemming from savings in foundry and forging operations, in machining, and in assembly costs and labor, have been accomplished by Ford engineers through extensive use of steel castings for heavily-stressed parts. Green sand and dry sand casting, and centrifugal casting are used, each chosen for specific reasons based on wide experimentation with new steel analyses and their adaptability to casting procedure. Ford engineers have found that for certain parts, steel castings show definite advantages in better service life, reduction in weight, and faster, easier production. By utilizing castings made to close tolerances, material has been saved, machining time reduced, and forging machinery and diemakers released to concentrate on those parts such as connecting rods, and axles where design requirements dictate forgings. Seven representative types of casting steels used in the Ford plant are listed in the table on the next page.



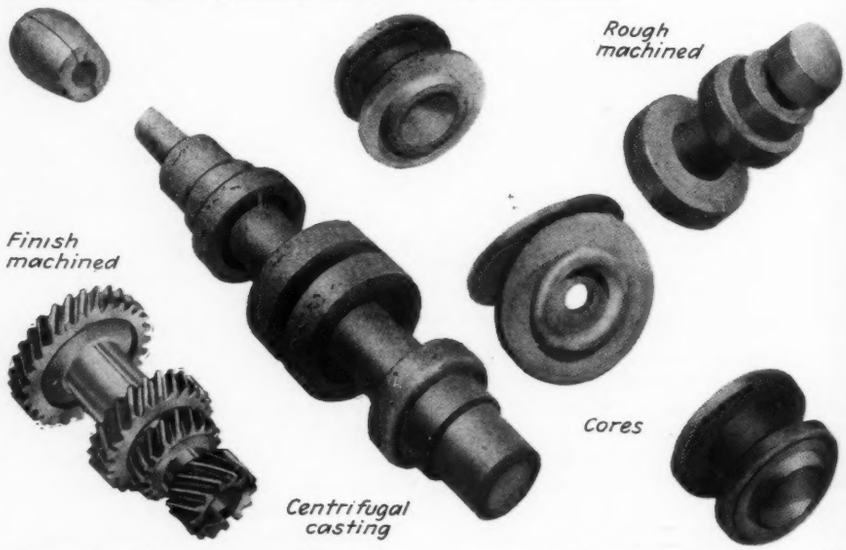
Etched sections show crystal structure in centrifugal casting runs perpendicular to line of action of forces on gear teeth. In the forged gear, weakness is found where flow lines run parallel and near the base of gear teeth. For discussion of the centrifugal casting process, see P.E. *p. 242–244, July 1938,* also *p. 179,* this issue.



Cast steel simplifies production, reduces unit costs. At the top is shown truck rear axle housing, sand cast, replacing tubular section which was swedged and to which two forgings were welded. One casting replaces three pieces, material was saved by varying wall thickness to place metal where needed. Lower left, rear axle end and spring perch, sand-cast in one piece, replacing two forgings butt-welded. Lower right, truck drive shaft universal end sand casting, replacing forging.



This sand casting in the rough weighs 8½ lb.; rough forging weighed 10 lb. 6 oz. Thus savings were not only made in material, but die costs and forging operations were eliminated and machining time reduced.



Centrifugally cast cluster gear showing cores, partly machined gear and finished gear. Dead load and impact tests show equal strength with forged gear. Comparative sections show better metal structure in casting.

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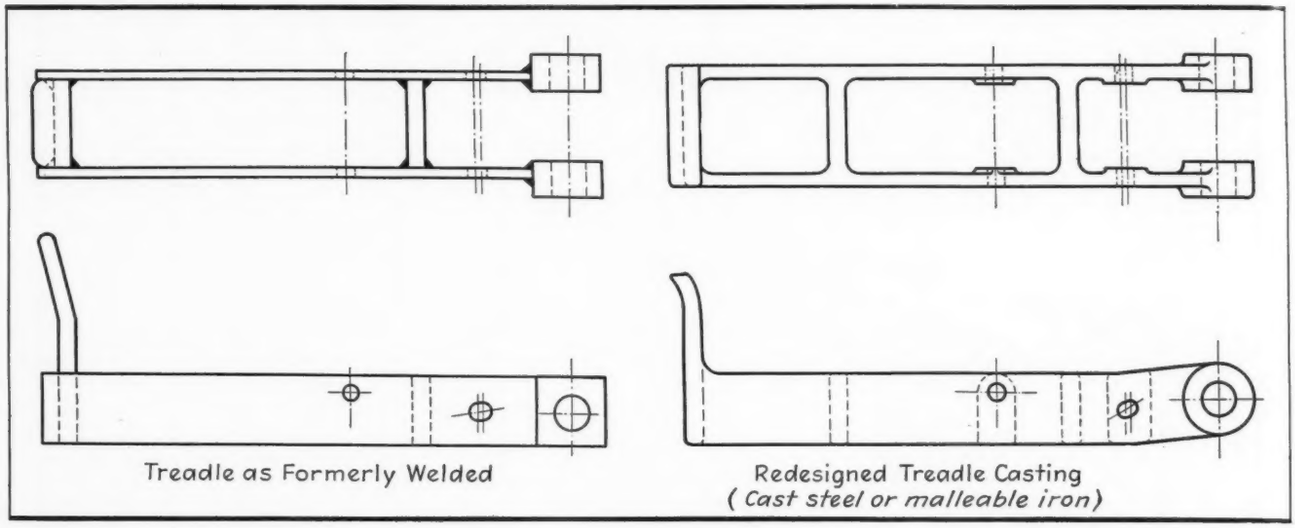
TYPICAL STEELS USED IN FORD AUTOMOTIVE PARTS

Type	Part	Analysis		How Cast	Heat Treatment, Deg. F.	Elastic Limit in 1,000 Lb. Per Sq. In.	Tensile Strength, in 1,000 Lb. Per Sq. In.	Elongation in 2 In. Per Cent	Reduction in Area Per Cent	Brinell Hardness
A	Steering Wheel Hub, Radius Rod Yoke	C 0.25–0.35 Cu 1.50–2.00 Si 0.60–0.80	Mn 0.40–0.60 P 0.05 Max. S 0.08 Max.	Sand	Normalized	53.8	71	18.5	33.0	163
B	Truck Ring Gears and Parts to be Carburized	C 0.18–0.25 Cu 0.50–1.50 Si 0.20–0.40 Mn 0.40–0.60 Mo 0.25–0.35	Cr 0.10 Max. P 0.05 Max. S 0.05 Max. Ni 1.65–2.00	Various	Normalize-Carburize, direct quench or reheat and oil quench and draw to Rockwell "C" 58–62	....	.....	....	....	...
C	Centrifugal Castings Trans. Countershaft and Differential Gear	C 0.30–0.38 Cu 0.50–1.50 Si 0.20–0.40 Mn 0.55–0.75	Mo 0.10–0.20 Cr 0.80–1.00 P 0.05 Max. S 0.05 Max.	Centrifugal	Normalized	47	85	21.0	35.0	160
				Sand	Normalized	44	87	18.0	28.	160
				Centrifugal	1500 Oil Qu, 950 Dr	136	140	7.0	14.0	502
				Sand	1500 Oil Qu, 950 Dr	135	144	6.0	13.3	302
				Sand	1500 Oil Qu, 850 Dr	142	148	5.0	14.6	321
				Centrifugal	1500 Oil Qu, 800 Dr	166	180	3.0	5.3	364
				Sand	1500 Oil Qu, 800 Dr	150	166	2.0	5.3	364
				Sand	1500 Oil Qu, 425 Dr	192	199	1.5	3.6	430
				Centrifugal	1500 Oil Qu, 355 Dr	212	218	0.75	3.0	477
				Sand	1500 Oil Qu, 355 Dr	207	221	0.5	3.0	477
D	Tractor Radius Rods, Tractor Front Axle, Rear Axle Flange, Plow Beams, etc.	C 0.35–0.45 Cu 0.50–1.50 Si 0.20–0.40	Mn 0.70–0.90 P 0.05 Max. S 0.05 Max.	Sand	Normalized	65.12	90.7	15.2	26.0	192
				Sand	1470 Water Qu, 1125 Dr	108.15	128.6	10.0	22.0	277
				Sand	1470 Water Qu, 1000 Dr	129.5	139.2	8.0	19.7	302
				Sand	1470 Water Qu, 850 Dr	152.9	157.5	5.5	13.6	341
				Sand	1470 Water Qu, 750 Dr	171.7	173.6	5.0	10.7	364
E	Truck Rear Axle Housing—Furrow Wheel	C 1.35–1.55 Si 0.90–1.10 Mn 0.40–0.60	Cr 0.08 Max. P 0.10 Max. S 0.08 Max.	Sand	Normalized	84	103	9.0	....	207
F	Crankshafts	C 1.35–1.60 Cu 1.50–2.00 Si 0.85–1.10 Mn 0.70–0.90	Cr 0.40–0.50 P 0.10 Max. S 0.08 Max.	Sand	Normalized	95.08	120.2	6.5	....	255
G	Piston	C 1.40–1.60 Cu 2.00–2.50 Si 0.90–1.10 Mn 0.80–1.00	Cr 0.15–0.20 P 0.10 Max. S 0.08 Max.	Sand	Normalized	85	104.7	7.5	....	229
Regular Malleable	.....	.....	.....	.....	Annealed	38	52	15.7	....	119
Ford Malleable	.....	.....	.....	.....	Annealed	43	60	14.0	....	140
Forged Steel	.....	C 0.30		.....	Normalized	60	85	27.0	....	165
Forged Steel	.....	C 0.40		.....	Normalized	80	110	20.0	....	225

Designs for speedier production

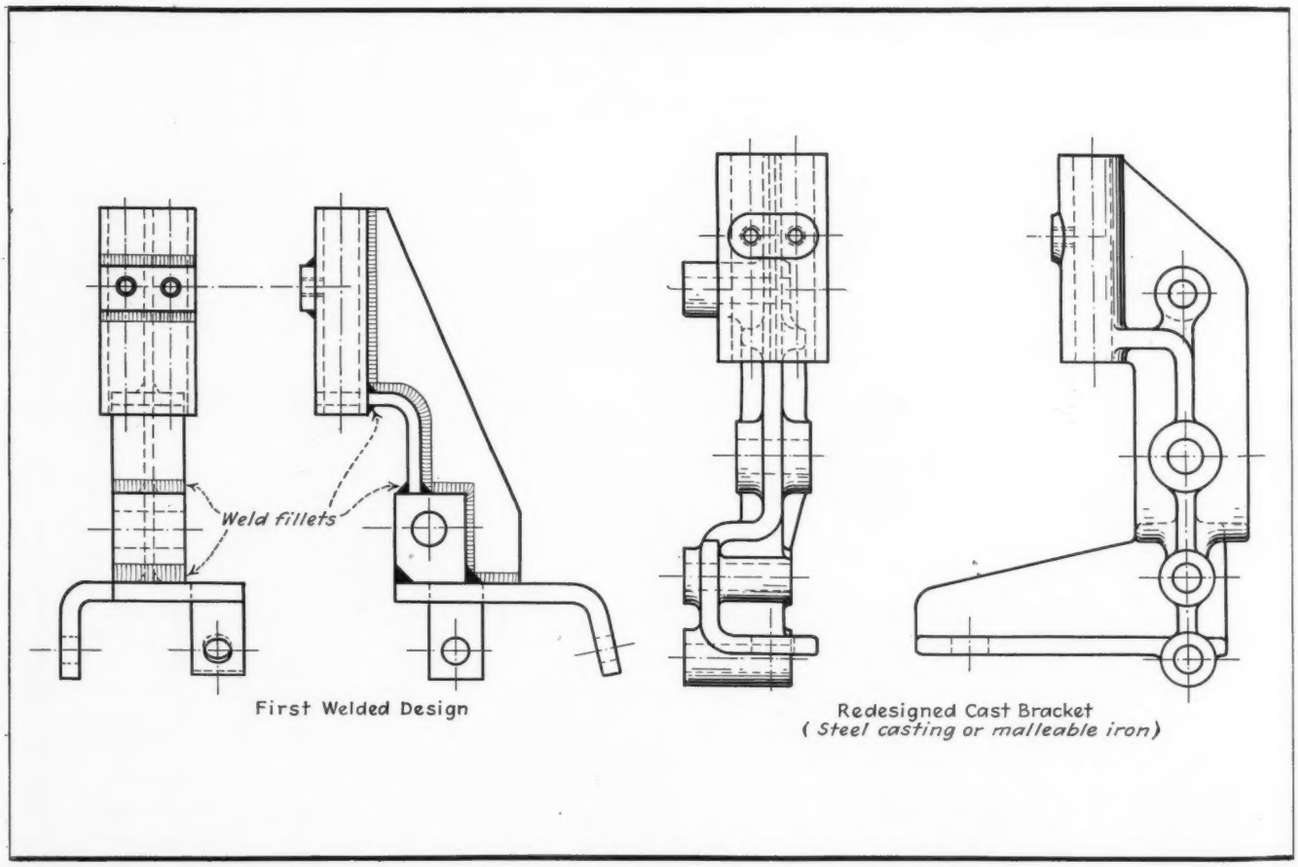
Castings Replace Welded Assemblies



Malleable iron or steel casting replaced built-up welded construction in this treadle for anti-aircraft guns.

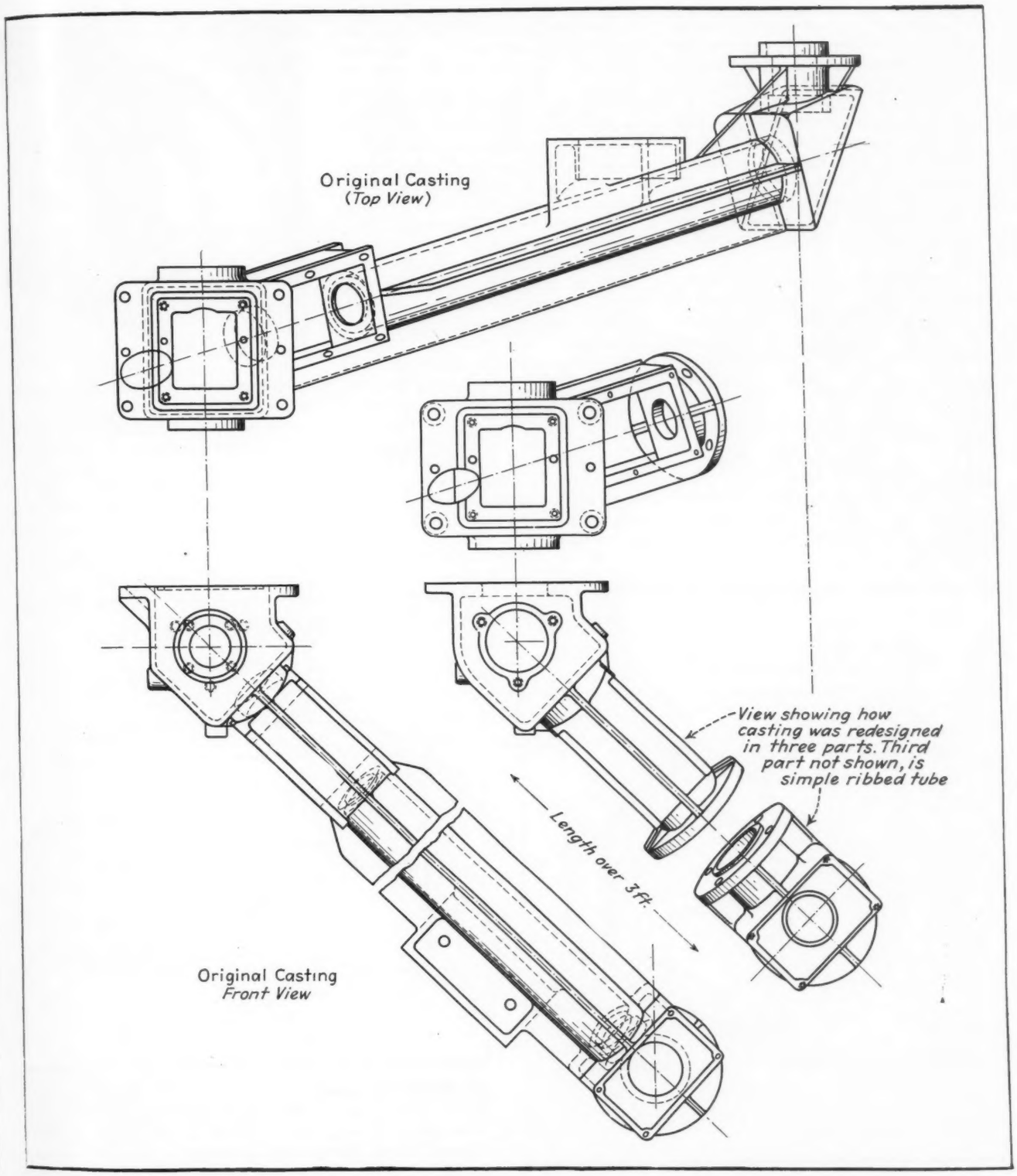
Welded treadle consisted of six pieces and necessitated 12 short fillet welds. Simplicity of casting is obvious.

This redesign is only one of many steps the War Department is taking to speed production of ordnance material.



Bracket, in first designs, was a six-piece welded assembly, an expensive construction for this small part. An influx of orders demanded mass production methods, hence bracket was redesigned to be made as a one-piece casting by modern high-production foundry methods. Radical changes in bracket shape and dimensions were caused by redesign of other parts in the assembly—also for reasons of higher production.

Component Parts Simplify Casting


Original Casting
(Top View)
View showing how casting was redesigned in three parts. Third part not shown, is simple ribbed tube
Length over 3 ft.
Original Casting
Front View

Three castings instead of one simplified production of aluminum-bronze casting for the elevating gear of a gun carriage. Originally designed as one casting over 3 ft. long, its shape made foundry work expensive and too slow, and the odd angles of the flanges made machining difficult. Army designers speeded production of the case simply by casting it in three flanged pieces which were bolted together after machining. Two of these redesigned component parts are shown above in comparison with original casting. The third part was simply a ribbed tube.

Where Spinning is Cheaper and Faster

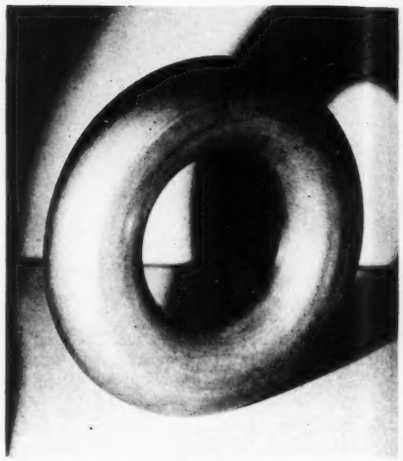
In small lots, parts designed for spinning can often be put into faster and cheaper production than parts designed for stamping. Tools for spinning can be made quicker, usually are cheaper, and can be used for different gages and materials. Taking advantage of these factors, designers not only are replacing stampings with spinnings for parts such as cams and covers, but also are fabricating complicated sheet metal parts by welding together segments cut from spun shapes.

Interdependent factors (gage, radii, depth and diameter of section, and ductility of material) follow same rules that operate in drawing. High carbon steel must be worked in dead annealed condition or by special technique. Stainless steels require several annealing and pickling operations in spinning deep sections.

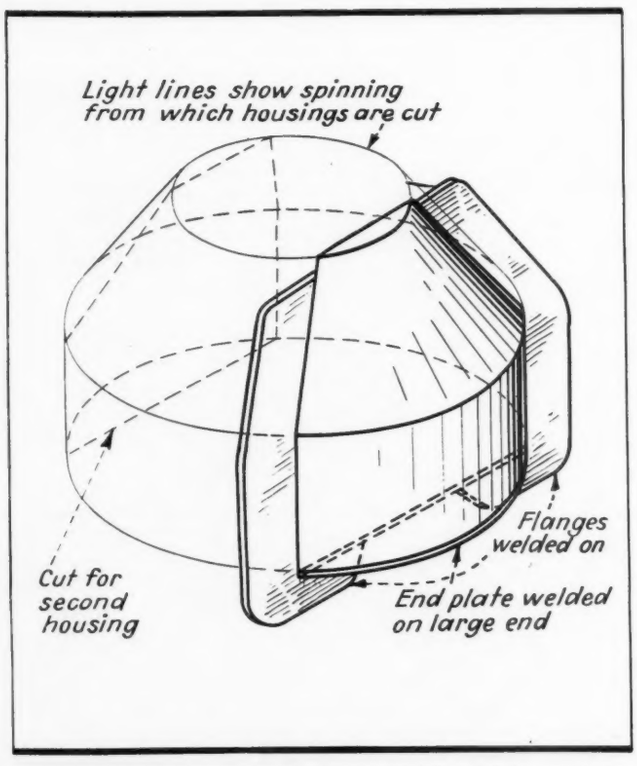
Maximum thicknesses are: brasses, bronzes and copper, up to ¼ in.; cold rolled steel, up to 9 gage; stainless steel, up to 11 gage. Minimum thickness depends on requirements of job. Copper 0.012 in. thick and steel 0.004 in. thick have been spun in small diameters; 22 gage steel can be spun commercially. Where minimum thickness of section is specified, the spinning is usually made from heavier gage metal because of reduction and variation in thickness. Sharpness of radii depends on thickness of metal; radii of ⅛ in. can be spun readily.

Tolerances on small spinnings can, at extra cost, be held to ±0.003 in. on outside diameters, and to ±0.005 in. on diameters of flanged holes. Common practice for production lots is to specify tolerances ranging from ±0.010 in. to ±0.030 in.

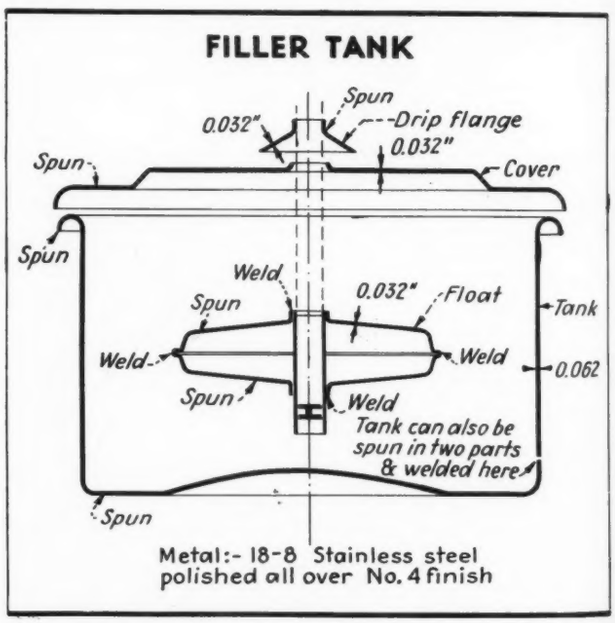
Aluminum reflectors which would require expensive deep drawing dies and an extra finishing operation, are made in lots of 5,000 by spinning. Steel lids 6½ in. in diameter, 22 gage, can be spun economically in lots of 2,000 to 3,000. For experimental work, six injectors for a new diesel engine design were spun to close tolerances from copper tubing 0.109 in. thick.



Light-weight elbows for welded pipe lines in Heil gasoline trucks are made by Milwaukee Metal Spinning Company by spinning 14 or 16 gage mild steel into the form shown. Two such spinnings are welded together into a doughnut shape, weld is ground smooth on outside surfaces, and doughnut is cut into four 90-deg. segments.


Light lines show spinning from which housings are cut
Flanges welded on
Cut for second housing
End plate welded on large end

Transmission housing is easily fabricated by welding flanges and end plate to a bowl-shaped section cut from a metal spinning. Shape of the spinning, made by Milwaukee Metal Spinning Company, is shown by light lines above. Two sections for transmission housings can be cut from each spinning.

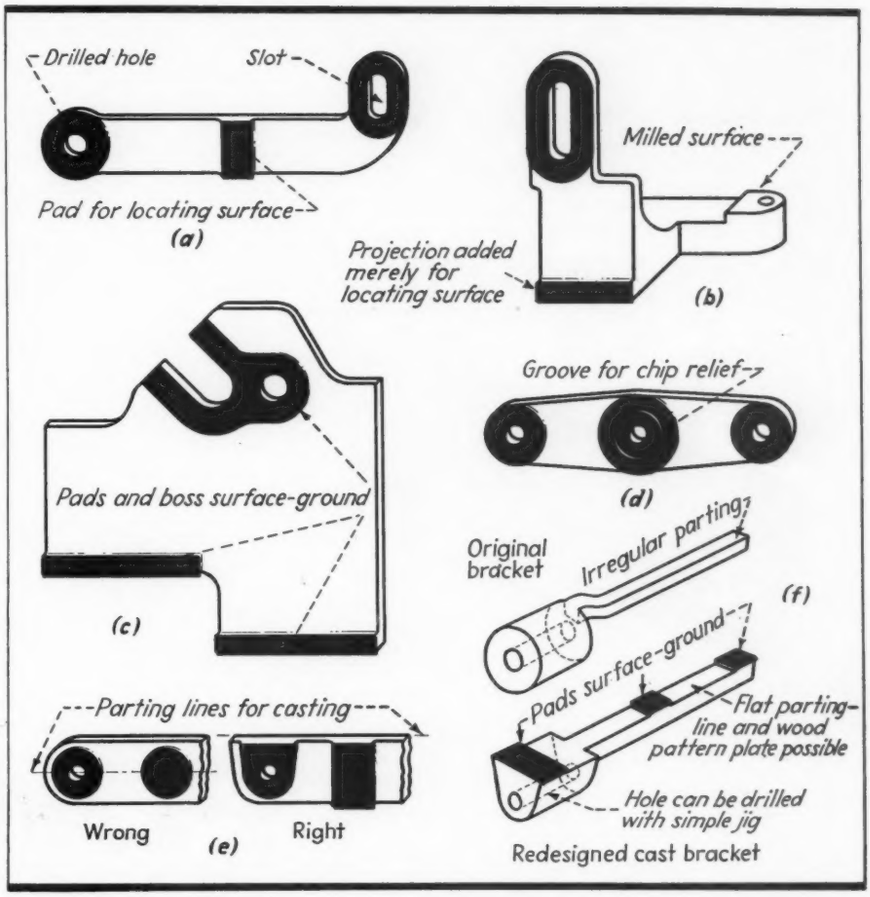


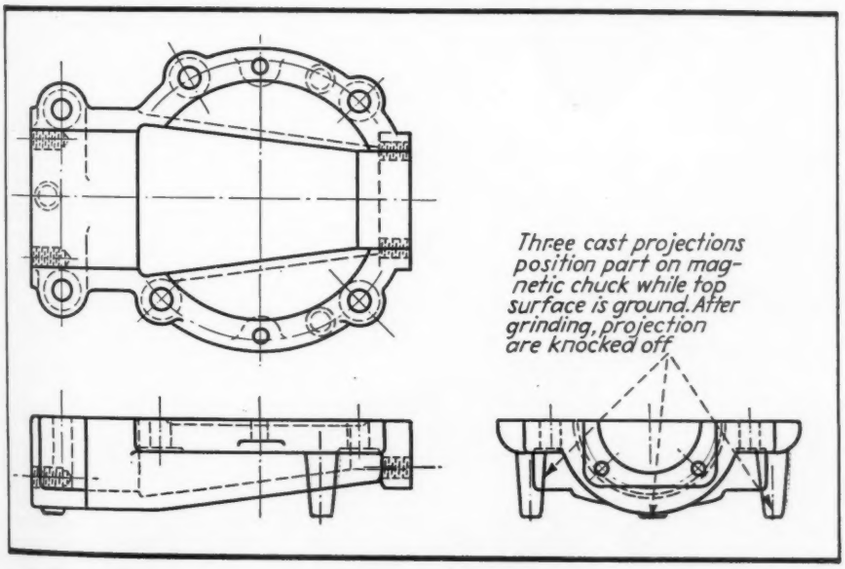
Bottle-filling tank, cover and drip flange are each spun in one piece by Milwaukee Metal Spinning Company from stainless steel. Tank is 20 in. in dia., 12 in. in depth. Float is 12 in. in dia. and is made by welding two spinnings as shown. Recent developments in low amperage welding equipment with close current control has made possible the welding of the thin gage stainless steel used. If a welded seam is permissible the tank can be made in two parts: (1) an upper rolled cylinder butt welded, with a spun upper edge; (2) a spun bottom. The two parts can then be seam welded together.

Tooling Up Simplified by Grinding

Grinding a flat surface as the first machining operation on cast, forged or hot-rolled parts speeds subsequent machining operations. The resultant finished surface accurately locates the part in jigs or on magnetic chucks and simplifies jigs and fixtures. Three or more bosses or pads raised to the same level and ground on a flat wheel are necessary for a stable surface; in designing odd-shaped parts it is often necessary to add bosses as shown in (*a*), (*b*), and (*c*), for this purpose. Bosses may also be placed at corners of large areas to avoid excessive grinding. Areas of bosses to be ground, shown in color, should be approximately equal. Grooves should be provided for chip relief in large bosses as shown in (*d*), otherwise chips will burn and slow up grinding operation. Two parallel surfaces can be ground simultaneously by straddle-grinding.

Flat surfaces in castings not only permit grinding as first operation, but also may make possible molding with wooden machine plates instead of all-aluminum pattern plates. Wherever possible, carry all bosses out to the edge of simple parts as shown in (*e*), so that the pattern can be placed entirely in drag. Typical redesign taking advantage of all these speed-ups is shown in (*f*).




Three cast projections position part on magnetic chuck while top surface is ground. After grinding, projection are knocked off

Fixtures are unnecessary for holding this odd-shaped casting during first grinding operation. Three small projections rest on Blanchard magnetic chuck and hold part in correct position for grinding top surface. After grinding, projections are knocked off with a hammer and smoothed off with grinder. Finished surface acts as locating surface for subsequent machining operations. Part is table drive cover for Blanchard vertical surface grinder.

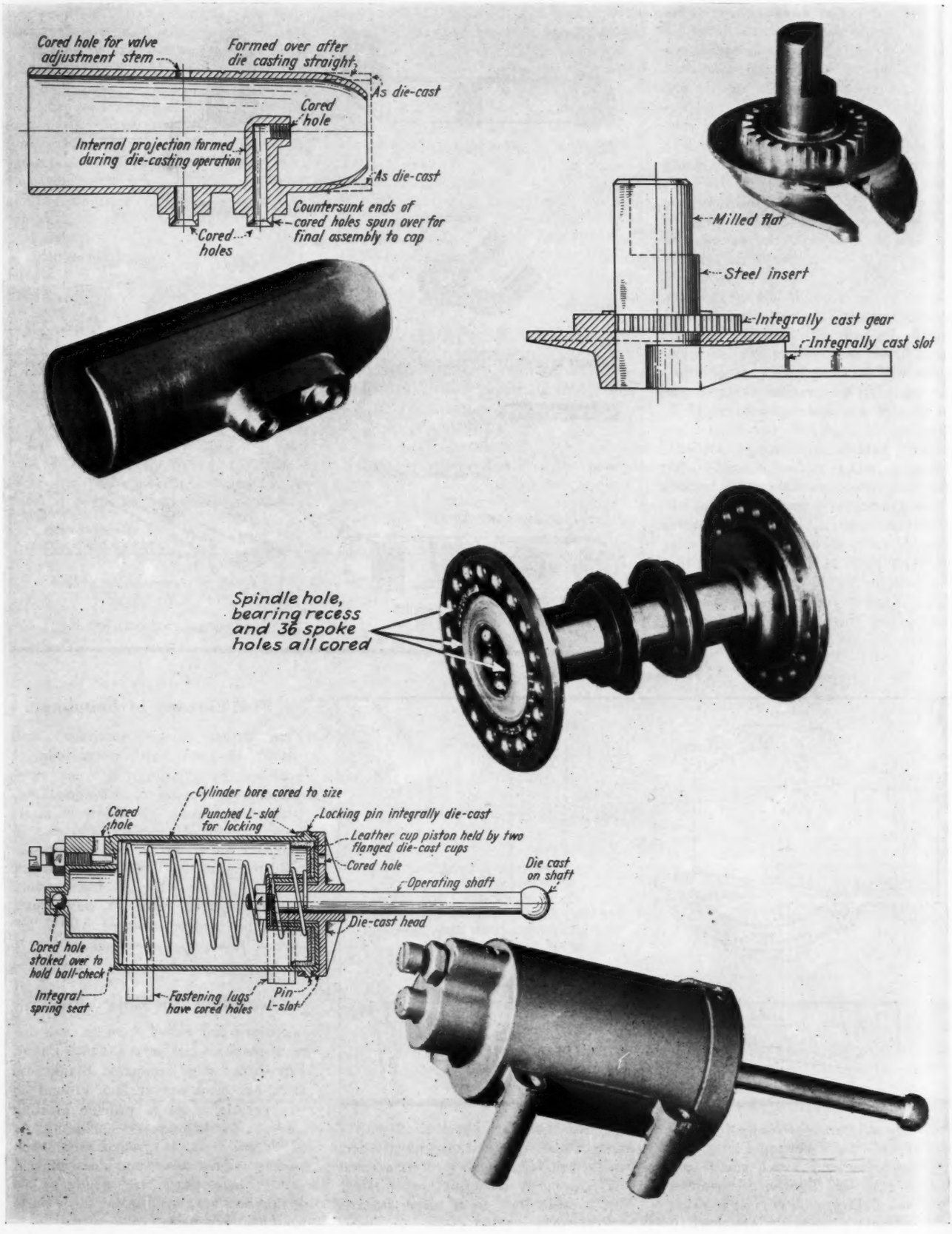
Fine Finishes by Grinding

Fine surface finishes, sometimes well within the super-finish range, can be achieved by grinding, in some cases eliminating lapping or subsequent finishing operations. Sunbeam Electric Company grinds surface 4½ in. in diameter on semi-steel cast compressor head to flatness of 0.000007 in. Surface finish is better than 6 microinches. Eclipse aviation grinds a pump part 3¾x3 in. to tolerances of 0.0002 in., surface finish of 4 microinches.

Grinding Hot Rolled Steel

Machined hot rolled steel is used for many machine gun parts at Colt's Patent Fire Arms Mfg. Company. Blanks cut from bar stock are surface ground on two parallel sides to provide locating surfaces for subsequent machining. As much as $\frac{1}{16}$ in. is ground from each side to remove scale and decarbonized skin. Some parts are as large as 14x5x2 in. Forging dies for these parts would be expensive.

Machining Operations Reduced by Die-Casting


Cored hole for valve adjustment stem
Formed over after die casting straight
As die-cast
Cored hole
Internal projection formed during die-casting operation
As die-cast
Countersunk ends of cored holes spun over for final assembly to cap
Cored holes
Milled flat
Steel insert
Integrally cast gear
Integrally cast slot
Spindle hole, bearing recess and 36 spoke holes all cored
Cylinder bore cored to size
Cored hole
Punched L-slot for locking
Locking pin integrally die-cast
Leather cup piston held by two flanged die-cast cups
Cored hole
Die cast on shaft
Operating shaft
Die-cast head
Cored hole staked over to hold ball-check
Integral spring seat
Fastening lugs have cored holes
Pin L-slot

Comparative Ratings for Die Casting Alloys

	Selection Factor	Aluminum Alloys A.S.T.M. Nos. 5, 7, 12	Brass	Magnesium Alloys A.S.T.M. Nos. 12 and 13	Zinc Alloys A.S.T.M. Nos. 21, 23, 25
Mechanical Properties	Tensile Strength	3	1 (strongest)	3	2
	Impact Strength	3	1 (toughest)	3	2
	Elongation	4	1 (most ductile)	3	2
	Dimensional Stability	2	1 (most stable)	2	3 (a)
	Resistance to Cold Flow	2	1 (most resistant)	2	3
	Brinell Hardness	3	1 (hardest)	3	2
Physical Constants	Electrical Conductivity	1 (highest)	2	3	2
	Thermal Conductivity	1 (highest)	2	4	3
	Melting Point	2	1 (highest)	2	3
	Weight, per cu. in.	2	4	1 (lightest)	3
Casting Characteristics	Ease, Speed of Casting	2	3	2	1 (easiest)
	Maximum Feasible Size	1 (largest feasible)	2	1 (largest feasible)	1 (largest feasible)
	Complexity of Shape	1 (greatest possible)	2	1 (greatest possible)	1 (greatest possible)
	Dimensional Accuracy	2	3	1	1 (most accurate)
	Minimum Section Thickness	2	3	2	1 (thinnest)
	Surface Smoothness	2	3	2	1 (smoothest)
Cost	Die Cost (b)	2	3	2	1 (lowest)
	Production Cost	2	3	2	1 (lowest)
	Finishing Cost (c)	3	2	3	1 (lowest)
	Cost per Piece (d)	2	3	2	1 (lowest)

(a) Through the use of a low temperature annealing treatment, Alloy No. 23 can be made virtually stable in dimensions.

(b) Dies for casting the low melting point alloys are least expensive and have longest life.

(c) Includes polishing and buffing expense as well as ease of applying all types of commercial finishes, both electro-deposited and organic.

(d) Based on die, material and fuel costs, production speed and machining and finishing costs.

Forging Specifications

ALUMINUM ALLOY FORGINGS

Aluminum alloy forgings can be made in all sizes in which steel forgings can be produced.

Tolerances on thickness dimensions, in addition to finish allowance on all longitudinal surfaces to be machined..... $+\frac{1}{32}$ in. $-\frac{1}{64}$ in.

Draft angles usually used vary from.....4 to 7 deg.
Avoid sharp corners and make radii as generous as possible, as in steel forgings.

STANDARD TOLERANCES FOR STEEL FORGINGS UNDER 100 LB. EACH

(Adopted by the Drop Forging Association, Feb. 11, 1937)

Table I — Thickness Tolerances
(Inches)

Net Weights Up To — Lb.	Commercial −	Commercial +	Close −	Close +
0.2	0.008	0.024	0.004	0.012
0.4	0.009	0.027	0.005	0.015
0.6	0.010	0.030	0.005	0.015
0.8	0.011	0.033	0.006	0.018
1	0.012	0.036	0.006	0.018
2	0.015	0.045	0.008	0.024
3	0.017	0.051	0.009	0.027
4	0.018	0.054	0.009	0.027
5	0.019	0.057	0.010	0.030
10	0.022	0.066	0.011	0.033
20	0.026	0.078	0.013	0.039
30	0.030	0.090	0.015	0.045
40	0.034	0.102	0.017	0.051
50	0.038	0.114	0.019	0.057
60	0.042	0.126	0.021	0.063
70	0.046	0.138	0.023	0.069
80	0.050	0.150	0.025	0.075
90	0.054	0.162	0.027	0.081
100	0.058	0.174	0.029	0.087

Table II — Shrinkage and Die Wear
(Inches)

Shrinkage: Lengths or Widths Up To — In.	Commercial + or −	Close + or −	Plus Die Wear: Net Wt. Up To — Lb.	Commercial + or −	Close + or −
1	0.003	0.002	1	0.032	0.016
2	0.006	0.003	3	0.035	0.018
3	0.009	0.005	5	0.038	0.019
4	0.012	0.006	7	0.041	0.021
5	0.015	0.008	9	0.044	0.022
6	0.018	0.009	11	0.047	0.024
Each additional inch add	0.003	0.0015	Each additional 2 lb. add	0.003	0.0015
For example			For example		
12	0.036	0.018	21	0.062	0.031
18	0.054	0.027	31	0.077	0.039
24	0.072	0.036	41	0.092	0.046
36	0.108	0.054	51	0.107	0.054
48	0.144	0.072	71	0.137	0.069
60	0.180	0.090	91	0.167	0.084

Table III — Mismatching Tolerance
(Inches)

Net Weight Up to — Lb.	Commercial	Close
1	0.015	0.010
7	0.018	0.012
13	0.021	0.014
19	0.024	0.016
Each addition 6 lb. add.....	0.003	0.002
For example —		
37	0.033	0.022
55	0.042	0.028
79	0.054	0.036
97	0.063	0.042

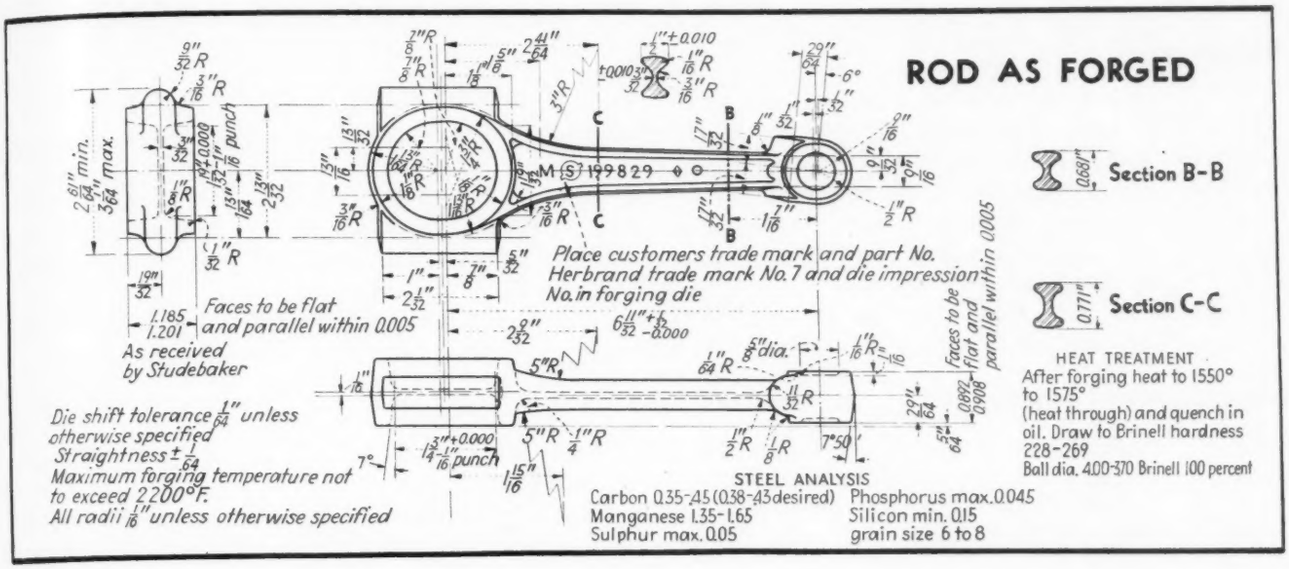
Table IV — Draft Angle Tolerances for Drop Hammer Forgings
(Degrees)

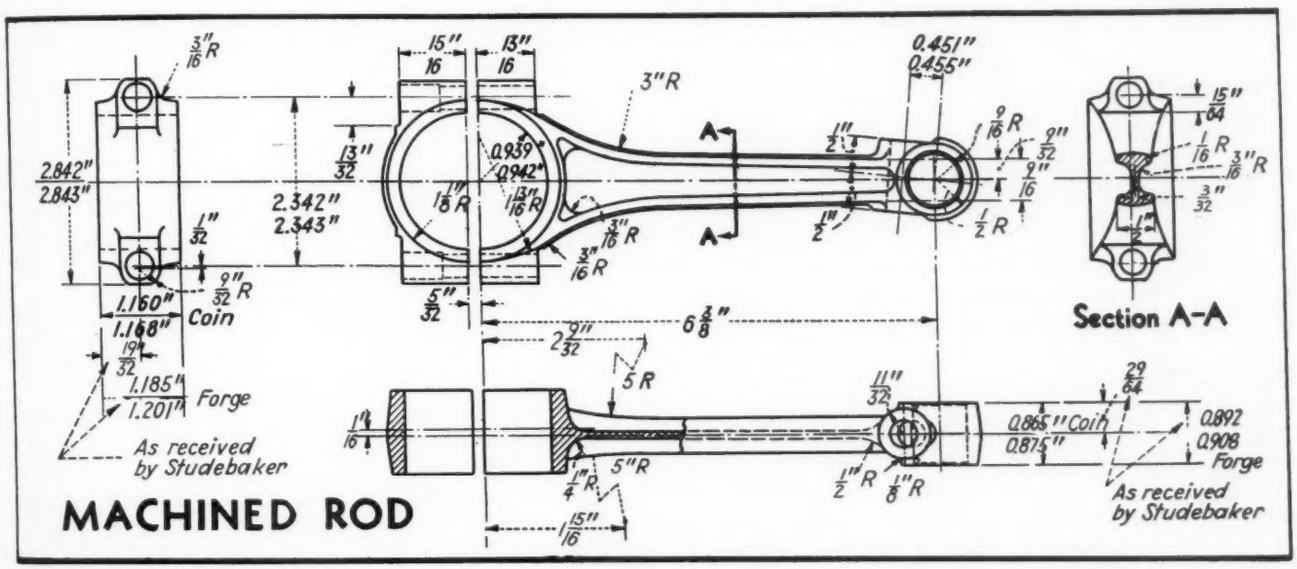
	Nominal Angle	Commercial Limits	Close Limits
Outside.....	7	0–10	0–8
Inside holes and depressions.....	10	0–13	...
	7	....	0–8

Draft Angle Tolerances for Upset Forgings
(Degrees)

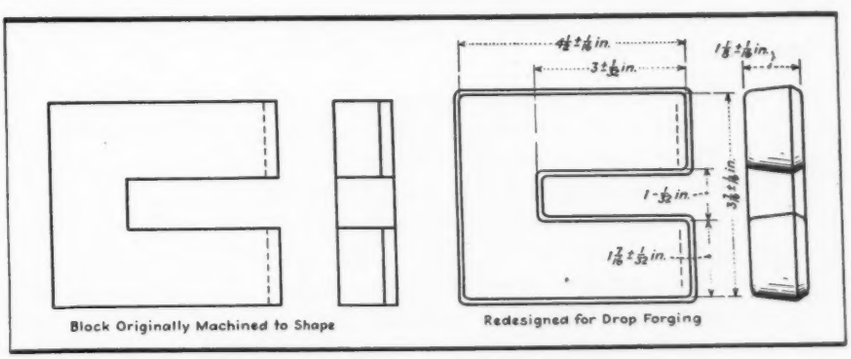
Outside.....	3	0–5	0–4
Inside holes and depressions.....	5	0–8	0–7

Forging to Close Tolerances


ROD AS FORGED
Section B-B
Section C-C
HEAT TREATMENT
After forging heat to 1550° to 1575° (heat through) and quench in oil. Draw to Brinell hardness 228-269
Ball dia. 4.00-370 Brinell 100 percent
Place customers trade mark and part No. Herbrand trade mark No. 7 and die impression No. in forging die
Faces to be flat and parallel within 0.005
As received by Studebaker
Die shift tolerance 1/64" unless otherwise specified
Straightness ± 1/64
Maximum forging temperature not to exceed 2200°F.
All radii 1/16" unless otherwise specified
STEEL ANALYSIS
Carbon 0.35-.45 (0.38-.43 desired)
Manganese 1.35-1.65
Sulphur max. 0.05
Phosphorus max. 0.045
Silicon min. 0.15
grain size 6 to 8



Forging details of connecting rod forged by The Herbrand Corporation for Studebaker Champions and detail drawing of the machined rod. Dimensions forged to finished size are shown in color on the drawing of the machined rod. The rods are Bonderized before boring the ends and after boring the ends are dip tinned. The Bonderizing serves as masking for the tinning and thus only the machined surfaces in the bores become tinned, as desired, all other surfaces remaining clean of tin. This saves tin and eliminates the operation of cleaning off surplus tin on surfaces where it is not desired. Faces of crank and wrist pin bosses are coined thus reducing machining time.



Demand for greater production of Army gun mounts led to the redesign of this small block. It was formerly machined of WD 1020 steel to tolerances of 1/32 in., but is now produced of the same material at a faster rate and more economically by drop forging. Note the liberal tolerances for the forging.

Parts Pressed From Metal Powders

DESIGN FACTORS

Formability.

Direct pressure must be applied to the entire cross-section of the part when molding. The amount of pressure required to obtain a required density in the compressed compact depends upon the malleability of the metal powder used.

Powdered metal materials have almost no lateral flow in the mold in response to pressures applied axially, therefore reentrant angles cannot be molded in the compact. If reentrant angles are required at planes normal to the axis, they must be machined to shape by conventional methods.

Hot pressing may be resorted to as a means of obtaining solid, pore-free compacts. With this method, however, the operation is slow, also die and maintenance costs are higher.

Size and Shape Limitations.

Capacity of press available determines the maximum cross-sectional area that can be compacted. Pressures for compacting vary from 30 to 60 tons per sq. in.

The working stroke of the press, the compression ratio of the powder selected and the density required, all determine the length of part which can be compacted. Compression ratios range between 2 to 1 and 20 to 1 for various metal powders. Length is limited by minimum density desired because frictional losses prevent the compacting pressure from being uniformly transmitted throughout the depth of the mold.

Shapes are confined to simple contours without undercuts in surface parallel to the axis.

Dimensional Tolerances.

Possible to hold very close tolerances in cross-sectional dimensions.

Tolerances in axial dimensions must be more liberal than those in cross-sections, because all of the variables add up in the length of the briquette or the sintered piece.

Tolerances for concentricity depend largely upon the clearance which must be provided between the force and the mold, since this clearance is likely to be all on one side when the compacting pressure is applied. Eccentricity can be corrected by operations subsequent to sintering, such as swaging or rolling, but this means additional cost.

Physical Properties.

Tensile strengths depend upon unit pressures employed to briquette the powders, the length of heat-treatment, and the care exercised in control of powder.

With heat-treating and quenching it is possible to produce from alloy powders, gears that have higher strength, wear and impact resistance than case hardened low carbon steel.

Strength and density may also be improved by re-pressing or cold working if the sintered piece is sufficiently malleable.

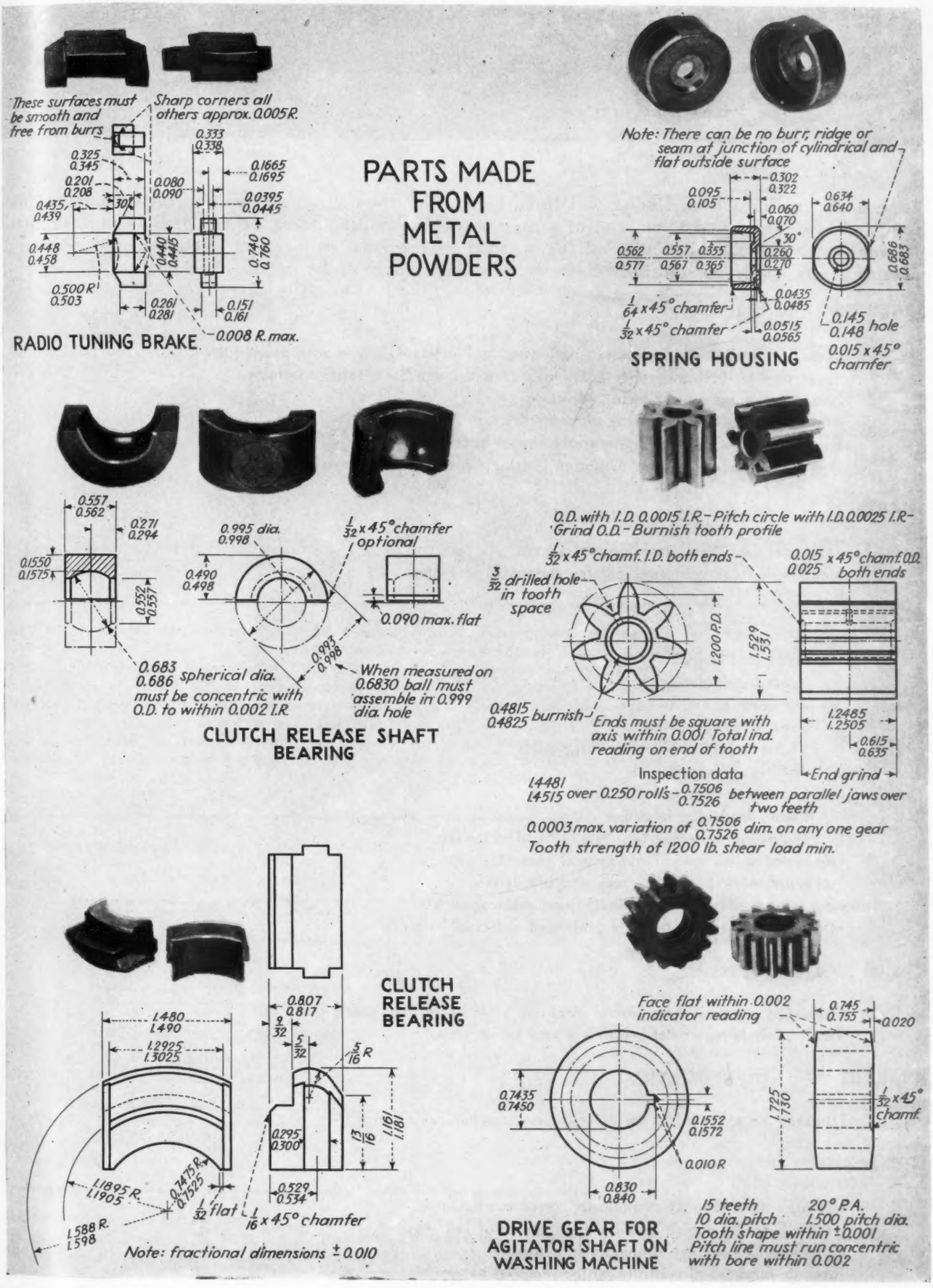
Design Advantages.

Parts having selected properties can be made. Two or more metal powders can be used to produce alloys which retain proportionately the individual characteristics of each constituent. Many special properties can be obtained by incorporating non-metallic ingredients with the metal powder, but this reduces strength.

Economical for the production of parts, which if made by other methods would involve considerable cost for machining operations in comparison with the cost of the material, or where scrap losses would be high. The more complicated the machining required by a piece made by other methods, the smaller the quantity which would have to be produced from metal powders in order to carry the expense for tools and equipment.

[Editor's Note—For the data here presented and the accompanying illustrations we are indebted to D. O. Noel, of the Metals Disintegrating Company and E. S. Patch of the Moraine Products Division, General Motors Corporation.]

PARTS MADE FROM METAL POWDERS



TRANSMISSIONS

Elements of simplified transmissions are listed here to show how drives and controls can be designed for faster and less costly production, and to suggest ways for shifting some of the production load onto subcontractors and manufacturers of parts such as bearings, seals, gears, motors, speed reducers, hydraulic units, electrical controls. Refer to cross-index, page 4, for details of methods.

BEARINGS

Cartridge, sealed bearings save machining and assembly where seals are required.
Snap-rings on ball and roller bearings permit through-bore, faster assembly.
Laminated shims speed bearing adjustment.
Pillow blocks simplify bearing mountings.
Removable end-plates facilitate machining of housings.
Low-melting-point alloy for mounting bearing sleeve eliminates machining of bore.

SHAFTS

Shims permit liberal machining tolerances.
Flexible shafts or couplings sidestep alignment problems.

GEARS

For faster production:
- Centrifugal casting
- Die-casting
- Pressed powdered metal
- Flame cutting and welding large gears
- Hobbing in gangs
- Shaving to eliminate grinding
- Flame hardening in gangs
- Induction hardening for gears integral with shaft

Laminated shims speed bevel gear alignment.
Sun gears, worm gears, etc., may simplify drives.
Gear motors or reducers eliminate designed-in gearing.
Flexible shafts eliminate bevel gears and universal joints.

CHAIN AND BELT DRIVES

Chain drives permit more liberal machining tolerances than gears.
V-belt or short-center flat belt drives may be simplest.

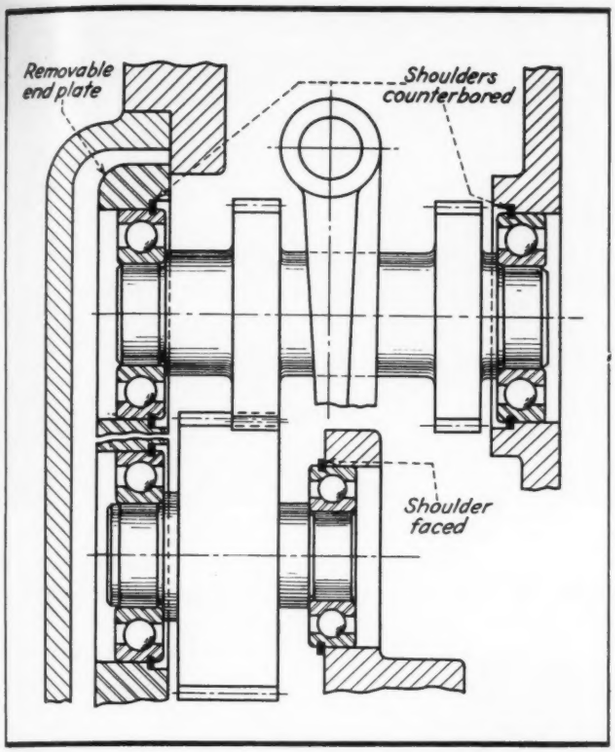
HYDRAULICS AND PNEUMATICS

Eliminate complicated motor drives, gears, mechanical controls.

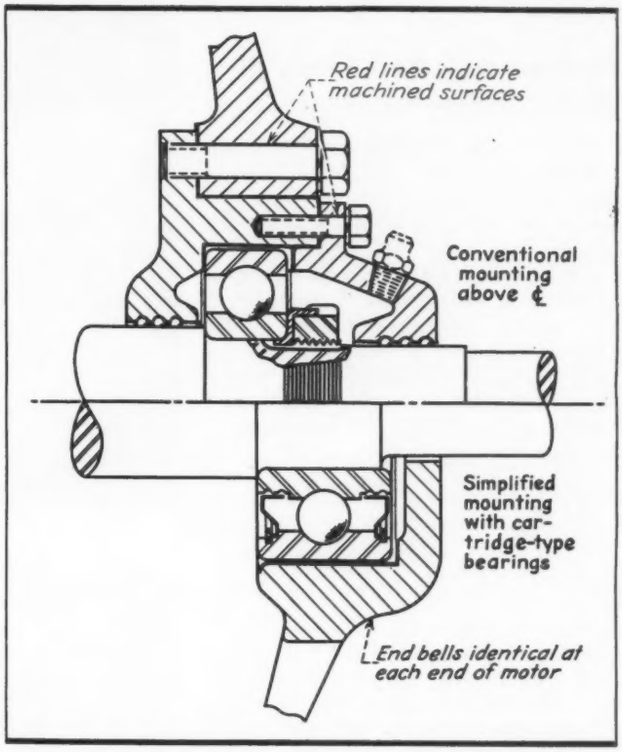
MECHANISMS

Linkages may simplify complicated drive mechanisms.
Needle bearings permit broader applications of linkages.
Flexible cables achieve simplicity in controls.
Intricate mechanical controls can be replaced by electrical controls.

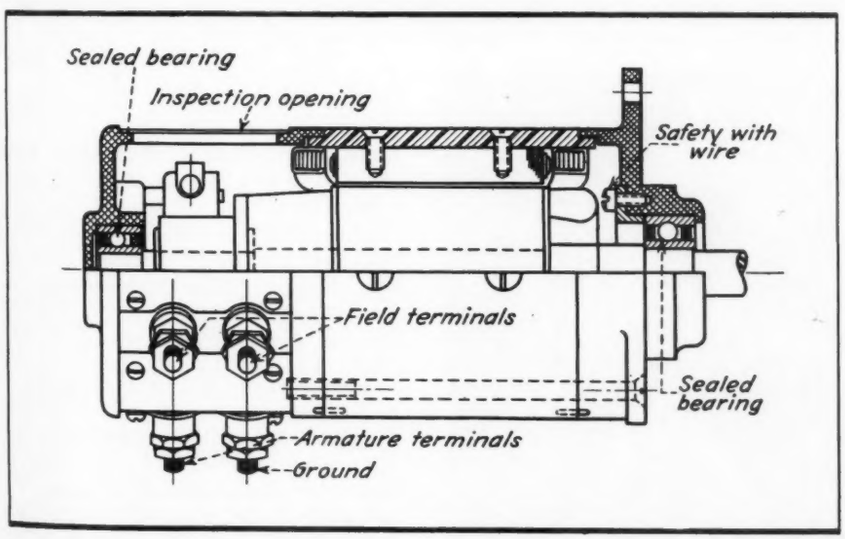
Designs for Simpler Bearing Mountings



Snap rings on bearings speed machining by permitting bores to be carried straight through. Typical example is this section of milling machine knee designed by Van Norman Machine Tool Company. Shoulders for three of snap rings are counterbored; fourth is simply faced. Compare with shaft assemblies shown on page 199, where snap rings would necessitate counterbore tool too large to pass through outer bores. Note also removable end-plate which simplifies machining and assembly.


Red lines indicate machined surfaces
Conventional mounting above ℄
Simplified mounting with cartridge-type bearings
End bells identical at each end of motor

Comparison of sealed cartridge-type bearing with conventional bearing mounting in motor illustrates simpler design, reduced number of parts, and savings in machining and assembly time possible. Red lines show machining required. This mounting, now being widely adopted for motors, is the "opposed" type; each bearing takes thrust only in one direction. Cartridge bearings are also suitable for "floating" or "fixed" mounting in machines. Clearance must be added to allow for shaft expansion and tolerances.



Motor for raising aircraft landing gear has sealed ball bearings. Chosen by Electric Specialty Company as simplest design of bearing and seal, it also is lightest in weight. Grease-packed bearings, after installation are not lubricated or inspected until main engine is overhauled after 600 hr. service.

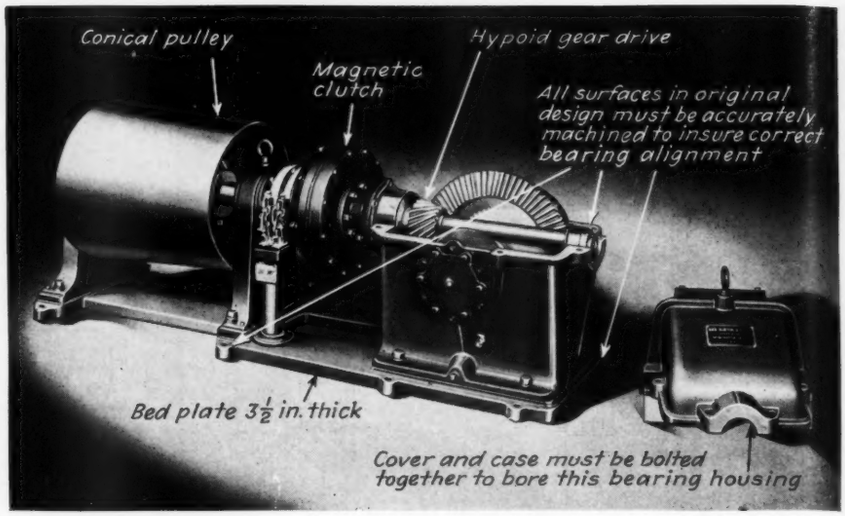
Aluminum-Tin Alloy Bearings Have High Load Capacity

An aluminum-tin alloy bearing developed by Federal-Mogul Corporation has shown interesting possibilities for the most severe operating conditions. Associated elements of design must be held within closer limits than with some of the other types of bearings. The crankshaft must be hard; the equivalent of either case hardened or Tocco hardened. The oil supply must be ample at all times, and a grooving system must be provided which will insure complete distribution within the bearing. Oil clearance must be not less than 0.00125 in. per inch of shaft diameter. In addition to its high load capacity, the AT-7 bearing is not subject to corrosion by such acids as may be formed in engine lubricating oils.

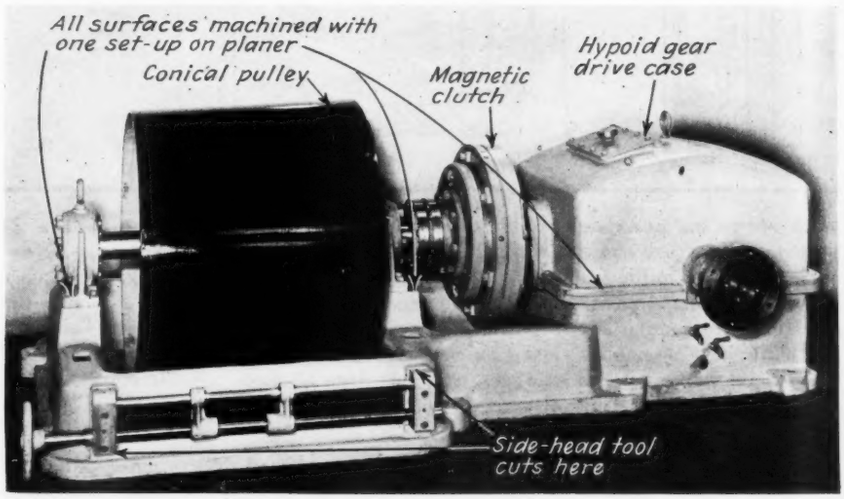
Pillow Blocks Simplify Drive Unit

Redesigned Bed Casting Reduces Machining

Adoption of pillow-block bearings and redesign of the bed castings saved much machining and assembly time in the production by Rice Barton Corporation of this hypoid gear drive unit for heavy paper machinery. Former design consisted of a 3½ in. thick bed plate casting, two bearing pedestals, gear case, and gear case cover, necessitating many machining operations. Also, bearings were mounted directly in the case, creating a complicated machining and bearing adjustment job.


Conical pulley
Magnetic clutch
Hypoid gear drive
All surfaces in original design must be accurately machined to insure correct bearing alignment
Bed plate 3½ in. thick
Cover and case must be bolted together to bore this bearing housing

Bed casting for the redesigned drive is of the box-frame type, with thinner sections, approximately the same total weight, but with greater rigidity than the former bed. Surfaces for pillow blocks and cover can all be machined in one operation. Appearance is also improved. Although not shown in these pictures, levelling of the unit during installation is facilitated by three small machined pads on the bed casting. A straight edge laid across any two of these pads provides a surface on which a level can be placed for accurate determination of bed levelness.


All surfaces machined with one set-up on planer
Conical pulley
Magnetic clutch
Hypoid gear drive case
Side-head tool cuts here

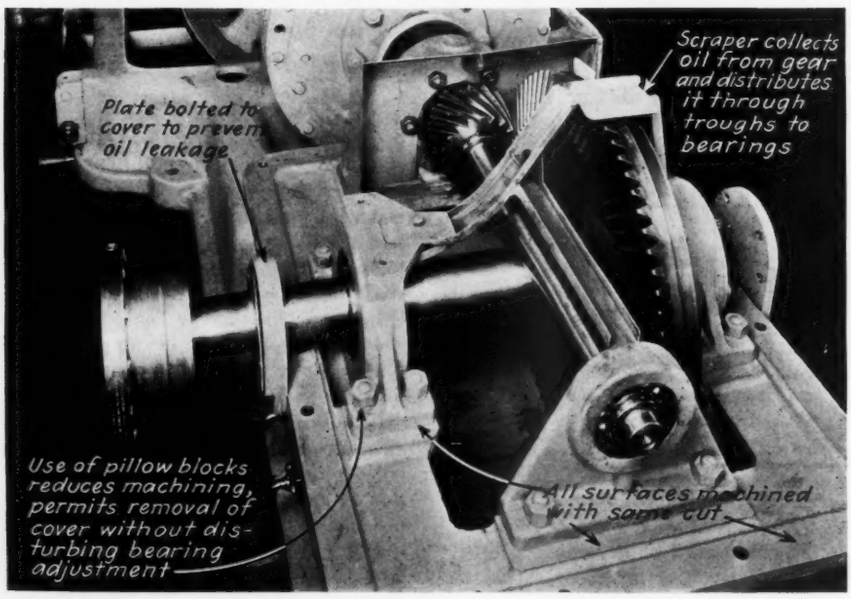
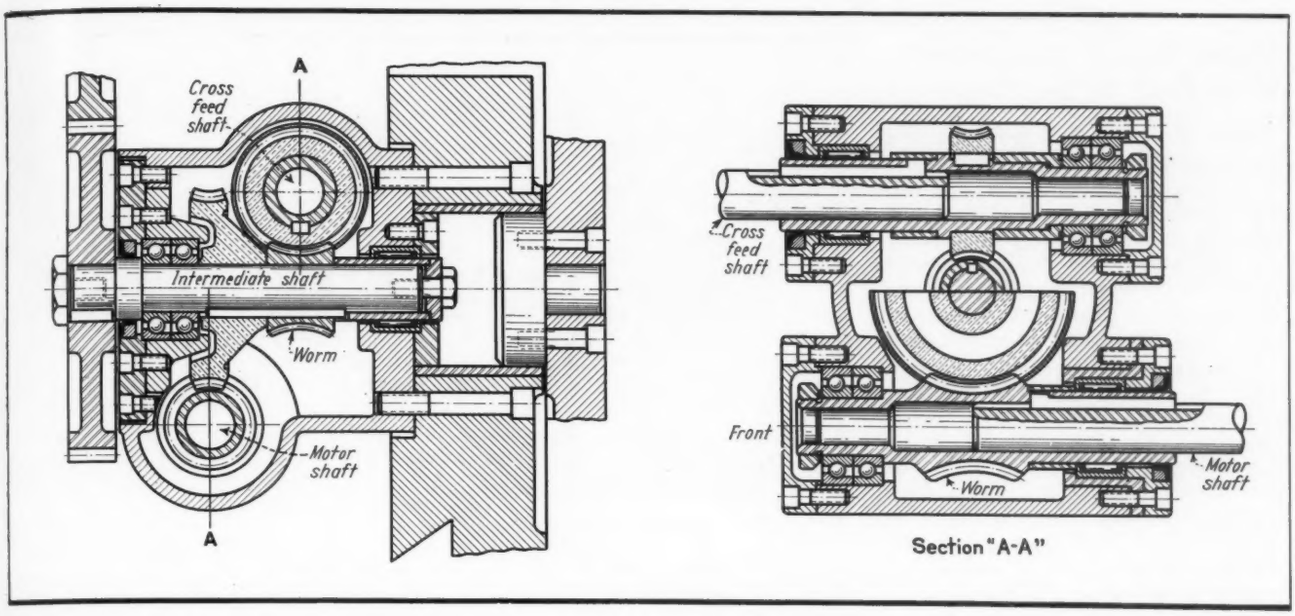


Plate bolted to cover to prevent oil leakage
Scraper collects oil from gear and distributes it through troughs to bearings
Use of pillow blocks reduces machining, permits removal of cover without disturbing bearing adjustment
All surfaces machined with same cut

Four pillow-block bearings for shafts of hypoid gears are set inside the redesigned gear case cover. Machining of these pillow blocks is simple when compared with machining of former bearing mountings. Oil seal housings for shaft are machined and assembled to bed as separate units; they are not taken off with the cover.

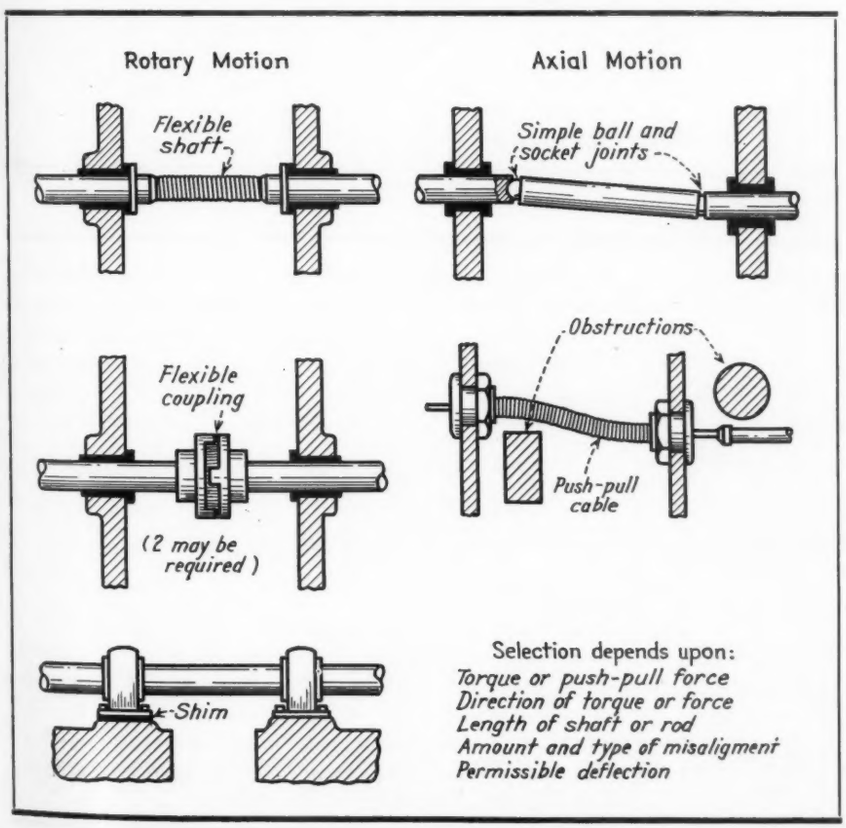
Bearings are lubricated by gravity from distributing troughs, two of which are shown here. Oil is collected by a scraper from the top of the large gear, which runs in an oil bath, and the collected oil is fed into the top of the trough system from whence it flows in equal amounts to each bearing. Adjustment and alignment of these hypoid gears is simplified by the use of laminated shims.

Worm Drive Reduces Number of Gears



Two pairs of Cone-type worm gears give a total reduction of 78⅛ to 1 in this gear box assembly. It is used in the rotary gear finishing machine produced by the Michigan Tool Company and takes the place of four spur gears, two pairs of bevel gears and one pair of conventional worm gears formerly used for the same purpose. The relatively small Cone-type gears are capable of greater reductions and heavier loads in proportion to their size.

Coupling Non-Aligning Elements



Sketches at left show ways to correct for misalignment of shafts or rods transmitting rotary or axial motion. Misalignment may be caused by machining tolerances, by unequal expansion of parts in which bearings are mounted, or by necessity for passing controls around obstructions. Flexible shafts and cables also can replace gears or linkages.

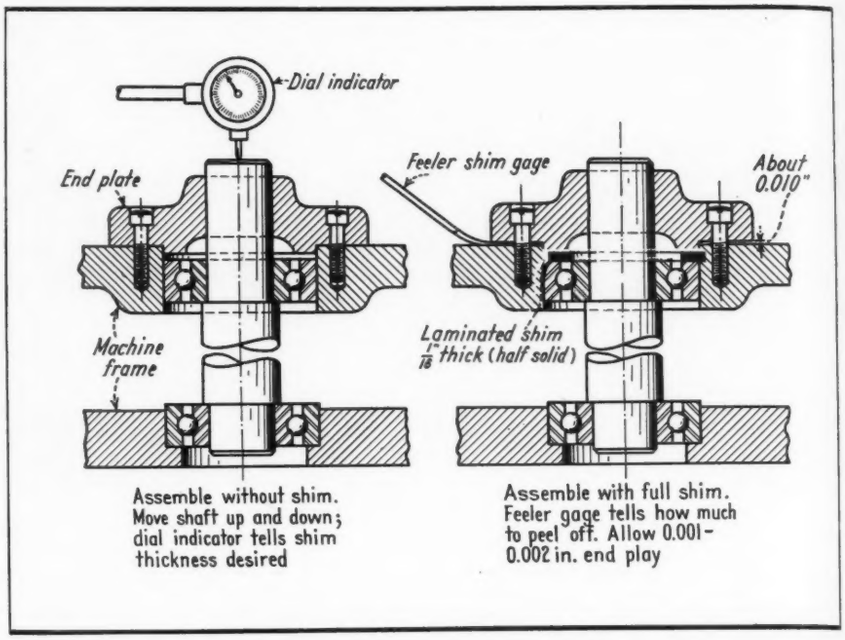
Hardened Precision Gears Made Without Grinding

Hardened precision gears for truck, tank, tractor and automobile transmissions are made by Spicer Manufacturing Company without grinding the teeth, thereby saving three to five hours production time. Gears are finish machined, teeth are hobbed and shaved, and the gears are then packed and put in a carburizing furnace. Before quenching, a plug is put in the bore to prevent warping. Large gears that have relatively thin webs are held clamped in a press while being quenched. After quenching, bores are ground to assure concentricity with the pitch circle. Resulting gears are within 0.0015 in. of exact dimensions.

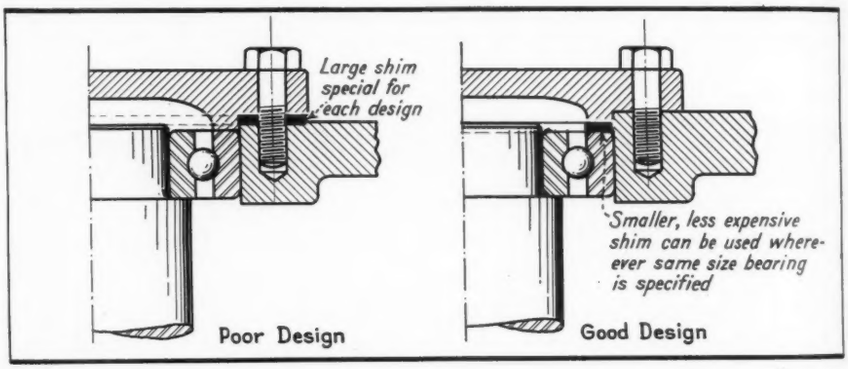
Assembly Time Reduced 10-20 Percent

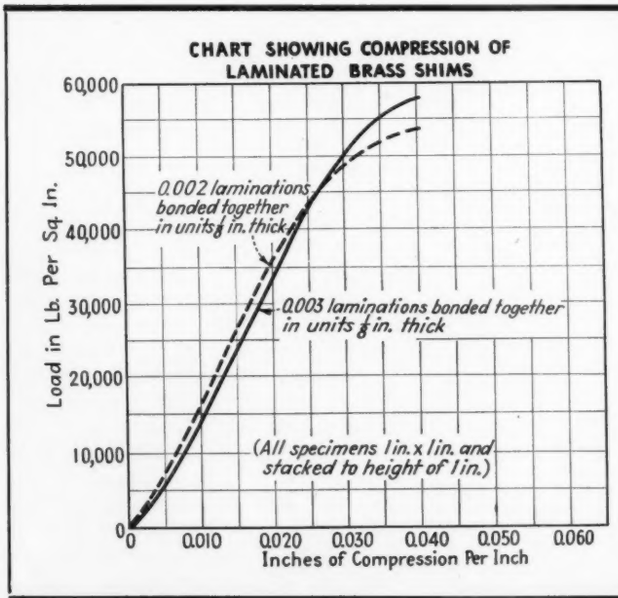
Shims Speed Adjustment With Ball, Roller Bearings

Although laminated shims have long been used in assembling and adjusting sleeve bearings, only recently have design engineers learned to use shims with ball and roller bearings to speed end-play adjustment of shafts and alignment of gears. Permitting simpler bearing mountings, laminated shims can save 10 to 20 percent assembly time, can reduce machining costs by permitting less exacting limits of accuracy, and can release to other jobs lathes used intermittently for machine-fitting shaft assemblies. Illustration shows two methods for determining correct shim thickness. Method shown at right can be used where shaft does not extend through end-plate. Since most shafts require some end play, allowances for this must be made.


Dial indicator
End plate
Machine frame
Assemble without shim. Move shaft up and down; dial indicator tells shim thickness desired
Feeler shim gage
About 0.010"
Laminated shim 1/16" thick (half solid)
Assemble with full shim. Feeler gage tells how much to peel off. Allow 0.001–0.002 in. end play

Simplest laminated shim to use is the annular type which fits against either the outer race or the inner race of the bearing. Two methods of design are shown. Obviously the smaller shim without bolt holes is more economical and easier to assemble. Shim manufacturers and users are now standardizing sizes of annular shims for use with standard ball and roller bearings. Principal point of controversy is standard clearance, now ranging from 0.002 to 0.005 in., between shim diameter and diameter of bore or shaft.


Large shim special for each design
Poor Design
Smaller, less expensive shim can be used wherever same size bearing is specified
Good Design



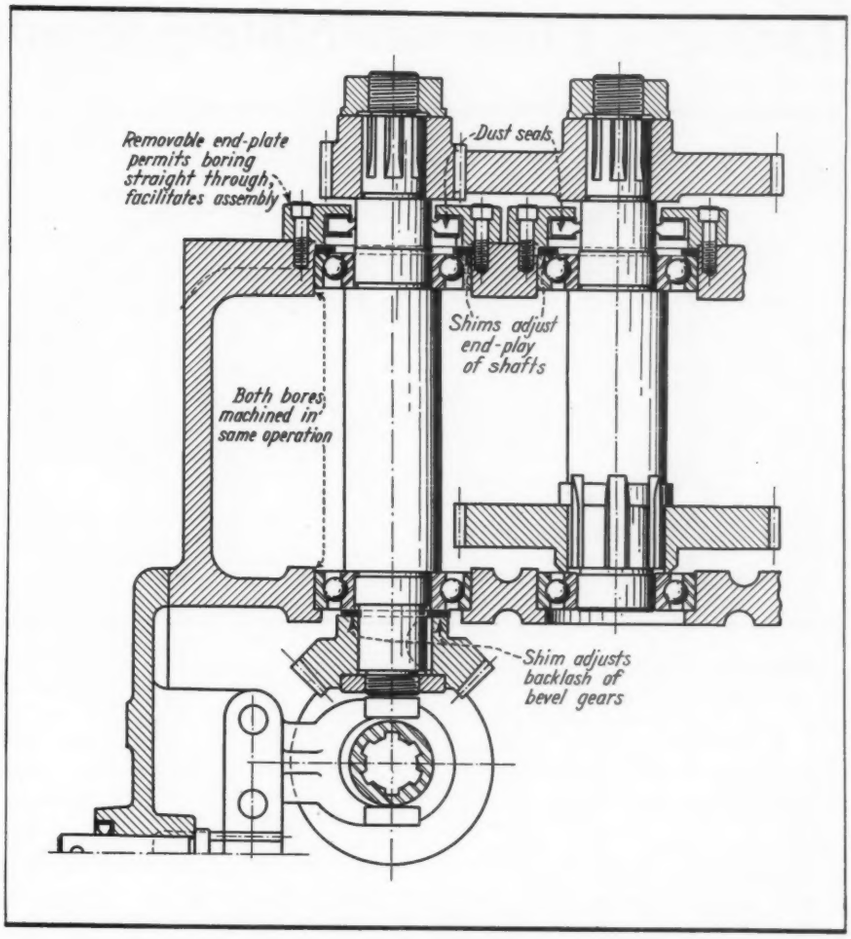
Commercial Tolerances for Laminated Shims

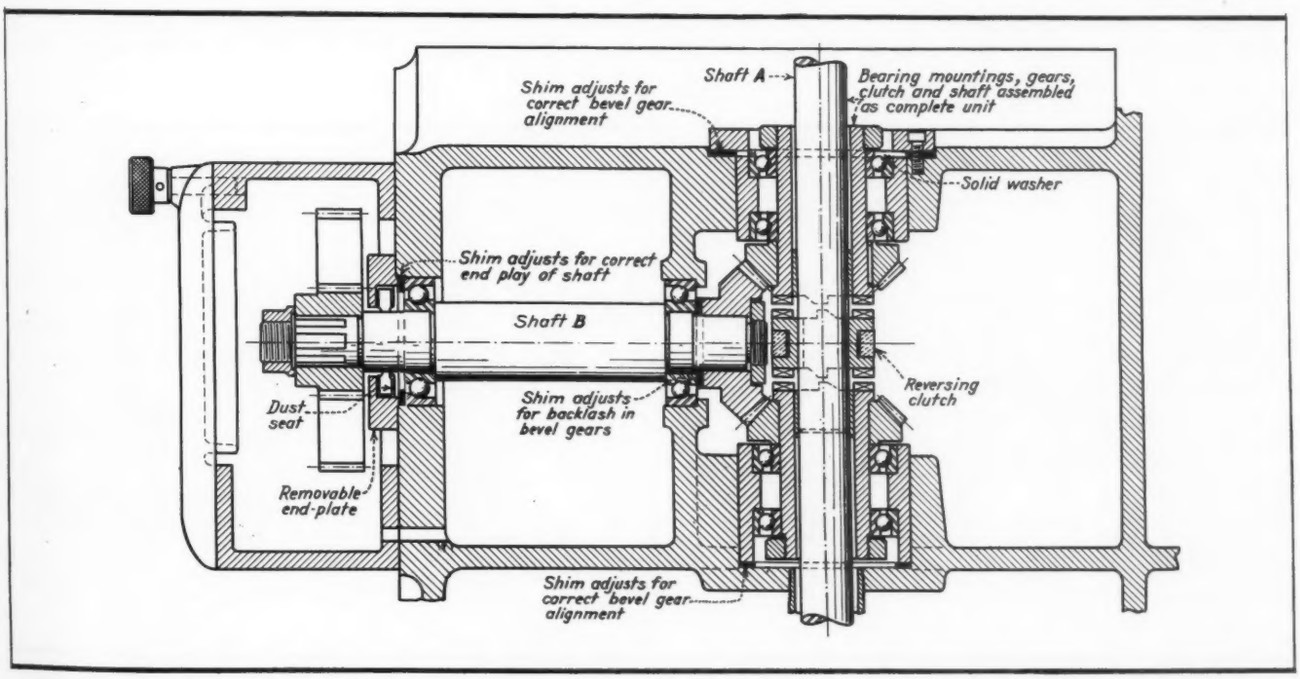
Nominal Total Thickness	No. and Size of Individual Leaves	Tolerance on Total Thickness
0.004	2 — 0.002 thick	±0.00025
0.006	2 — 0.003 "	±0.00025
0.006	3 — 0.002 "	±0.00025
0.009	3 — 0.003 "	±0.00025
0.008	4 — 0.002 "	±0.0006
0.012	4 — 0.003 "	±0.0006
0.030	15 — 0.002 "	±0.0020
0.030	10 — 0.003 "	±0.0020

Data Courtesy Laminated Shim Company and A. B. Willi, Chief Engineer, Federal-Mogul Corporation

How laminated shims simplify design of ball bearing mountings is clearly shown in this Van Norman machine tool drive. Bores for inner and outer bearings are machined to same diameter; removable end-plate permits boring straight through outer bearing housing and facilitates assembly of shaft, bearings and dust seal. This end-plate principle is applied in drive housings of many Van Norman machines, with considerable savings in machining and assembly time. Two shim adjustments are necessary in assembling shaft at left: one for correct backlash of bevel gear, and one for proper end-play of shaft. Only end-play adjustment is required for shaft at right. Bearings were formerly fitted by assembling drive, testing backlash, disassembling, machining a few thousands off the shaft or gear, reassembling, etc., until desired adjustment was obtained.

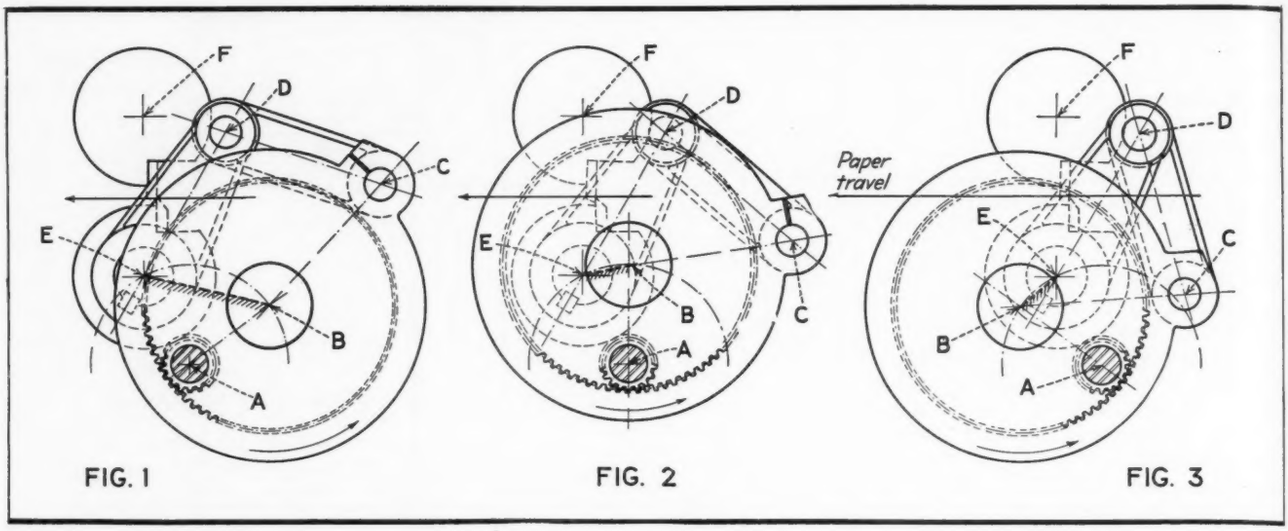
In these applications, shaft and end-plate dimensions are calculated for shim thickness of 0.052 in. Shims as purchased are 0.062 in. thick ($\frac{1}{16}$ in.), half solid, half laminated for economy. Therefore, in assembling parts machined with absolute accuracy, it is necessary to peel off 0.010 in. from each shim. Actually, cumulative machining tolerances of −0.010 to +0.020 in. are possible. Laminations for bevel gear alignment are 0.002 in. thick; for ordinary bearing adjustments, 0.003 in.


Removable end-plate permits boring straight through, facilitates assembly
Dust seals
Shims adjust end-play of shafts
Both bores machined in same operation
Shim adjusts backlash of bevel gears

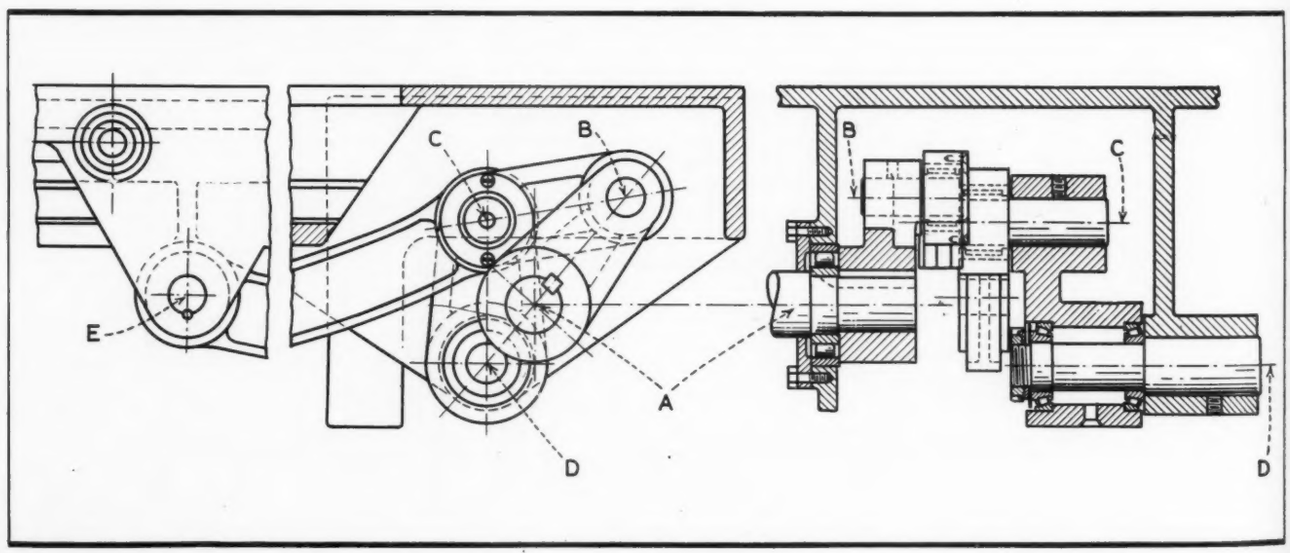

Shim adjusts for correct bevel gear alignment
Shaft A
Bearing mountings, gears, clutch and shaft assembled as complete unit
Solid washer
Shim adjusts for correct end play of shaft
Shaft B
Reversing clutch
Dust seal
Shim adjusts for backlash in bevel gears
Removable end-plate
Shim adjusts for correct bevel gear alignment

Bevel gears are easily assembled and adjusted in this reversing gear drive for Van Norman milling machine. On shaft *A*, bearing mountings, bearings, gears, clutch and shaft are pre-assembled into unit which is easily slid into place in the machine housing. Complicated adjustment and alignment of the bevel gears is facilitated by three laminated shims as shown. Proper end play (0.001 to 0.002 in.) of shaft *B* is adjusted by shim set between end-plate and ball bearing. Van Norman Machine Tool Company estimates a saving of 30 percent on bevel gear alignment, and a saving of 20 percent in assembling where adjustment of end-play is important to accuracy and life of the machine.

Linkages Eliminate Sliding Members

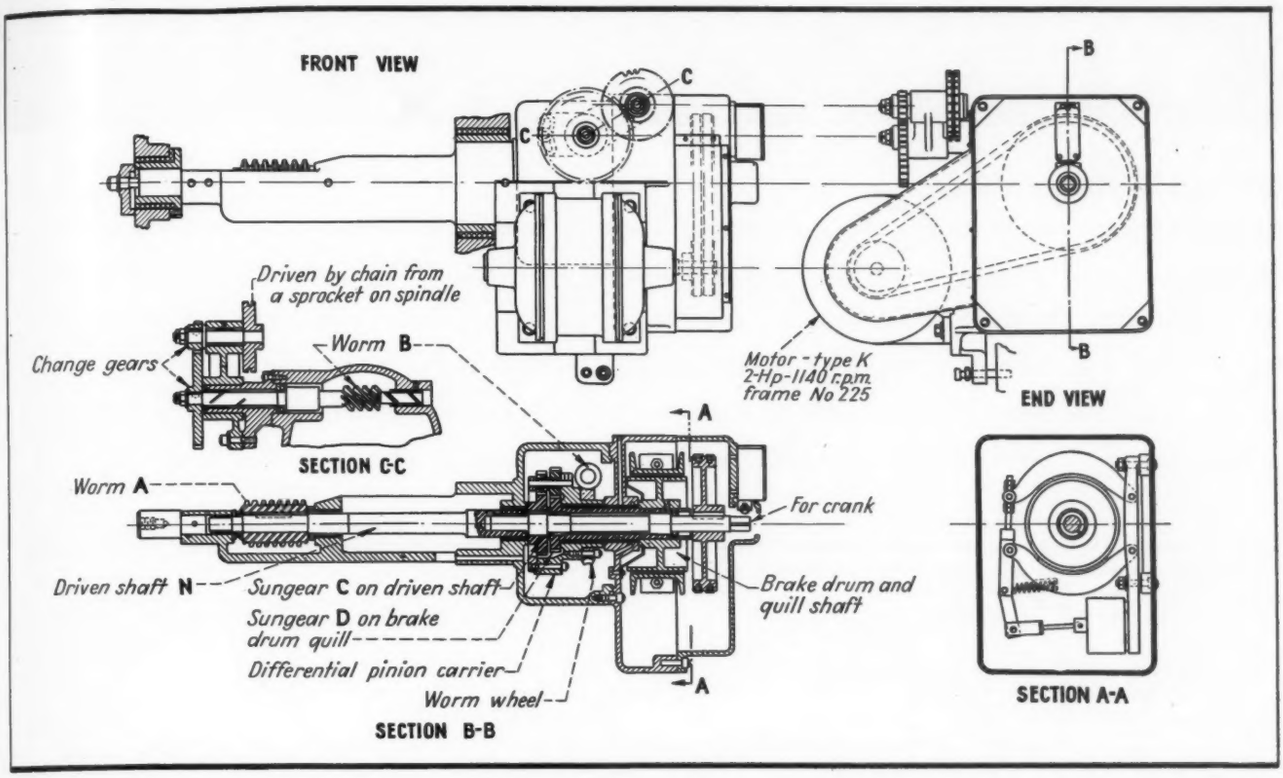


Mechanism consisting essentially of two cranks and a link imparts a variable rotary motion to knife bars of sheet and paper-board cutting machinery made by S & S Corrugated Paper Machinery Company. A Reeves variable-speed unit drives shaft *A* having an integral pinion which drives an internal gear mounted on shaft *B*. Pin *C* which is fixed to the internal gear ring drives link *CD* which in turn rotates crank *DE* keyed to lower knife shaft *E*. Gears, not shown in illustration, on shaft *E* mesh with gears on *F* the upper knife shaft. Schematically the linkage consists of a driving crank *BC*, a follower link *CD*, a driven crank *DE*, and a frame link *BE*. The internal gear shaft *B* is carried on the web of a large worm-wheel segment which is free to turn on shaft *A*. Thus by means of a mating worm the shaft *B* can be adjusted through an arc *BE* and thereby change the length or eccentricity of frame link *BE*, so that a quick knife action can be used to cut long sheets, a slow knife action to cut short sheets and an intermediate speed to cut medium length sheets. In Fig. 1 the position of shaft *B* is shown when adjusted to cut the longest sheets. Fig. 2 shows the position of shaft *B* when adjusted to cut medium length sheets. Fig. 3 shows the position of shaft *B* when adjusted to cut the shortest sheets. The driving worm for turning the worm segment that carries shaft *B* is geared to the speed adjusting screw on the Reeves unit, thus the worm segment and the driving speed can be adjusted simultaneously. As shown in the illustration, axes of rotation for shafts *A*, *E* and *F* are fixed.



Quick return "kicker" mechanism consisting only of cranks and links is used on a paper folding machine made by S & S Corrugated Paper Machinery Company. Drive crank *AB* is keyed on driving shaft *A*. Crank *AB* drives link *BC*, which in turn drives the driven crank *CD*. Pin *C* drives "kicker" link *CE*. Link *CE* imparts a reciprocating motion to a carriage which is constrained to move in a straight line by ways in the machine frame. Carriage travels on ball bearing rollers riding on flat steel tracks in machine frame. Side thrust of carriage is resisted by ball bearing rollers turning on vertical pins mounted in carriage. The rollers travel in ways machined in frame.

Lathe Feed Design to Speed Production



Automatic lathe feed mechanism provides a drive for obtaining feed motions which are synchronous with the speed of the lathe spindle on shell machine, designed by the machine tool industry, working through the Defense Committee of the National Machine Tool Builders' Association. Feed drive arrangement illustrated also provides a constant fast speed for quick positioning of tools and a stop.

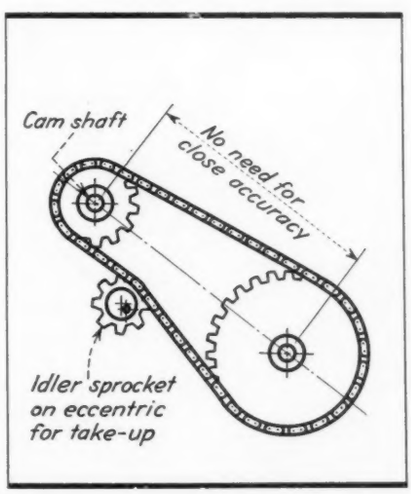
Cam drums, not shown in the illustration, for tool feeds are driven by worm *A* keyed on driven shaft *N*. Shaft *N* can be driven by V-belt motor drive or by worm *B* depending upon which elements are locked in the system. The drive for feeding or cutting movements is by chain from a sprocket on the lathe spindle to the gear box, through change gears to worm *B*. Worm *B* drives a wormwheel keyed to a differential pinion carrier, thus the pinion carrier always revolves synchronously with the lathe spindle.

Sun gear *C* is keyed to the driven shaft *N*, the other sun gear *D* is integral with the brake drum quill shaft which revolves freely on the driven shaft. The brake drum can be stopped by a solenoid actuated brake, Section *A-A* shows the arrangement.

In the stop position, both brake and motor are not energized. also inertia holds driven shaft *N* stationary, and the rotation of the differential carrier causes sun gear *D* and the brake drum to rotate idly. In the feed position, the solenoid brake is energized so that sun gear *D* is held stationary, and the rotation of the differential carrier causes driven shaft *N* to rotate synchronously with the lathe spindle, thus idly rotating the motor armature through the V-belts. In the fast feed motion position motor is energized and the brake solenoid de-energized, so that driven shaft *N* is rotated rapidly by the motor V-belt drive. In this position sun gear *D* idly drives planetary pinions and quill shaft.

The electrical control, which can be either manual or automatic, is a three position switch connected for current off, current to brake solenoid, and current to motor.

Chain Drive Replaces Gears

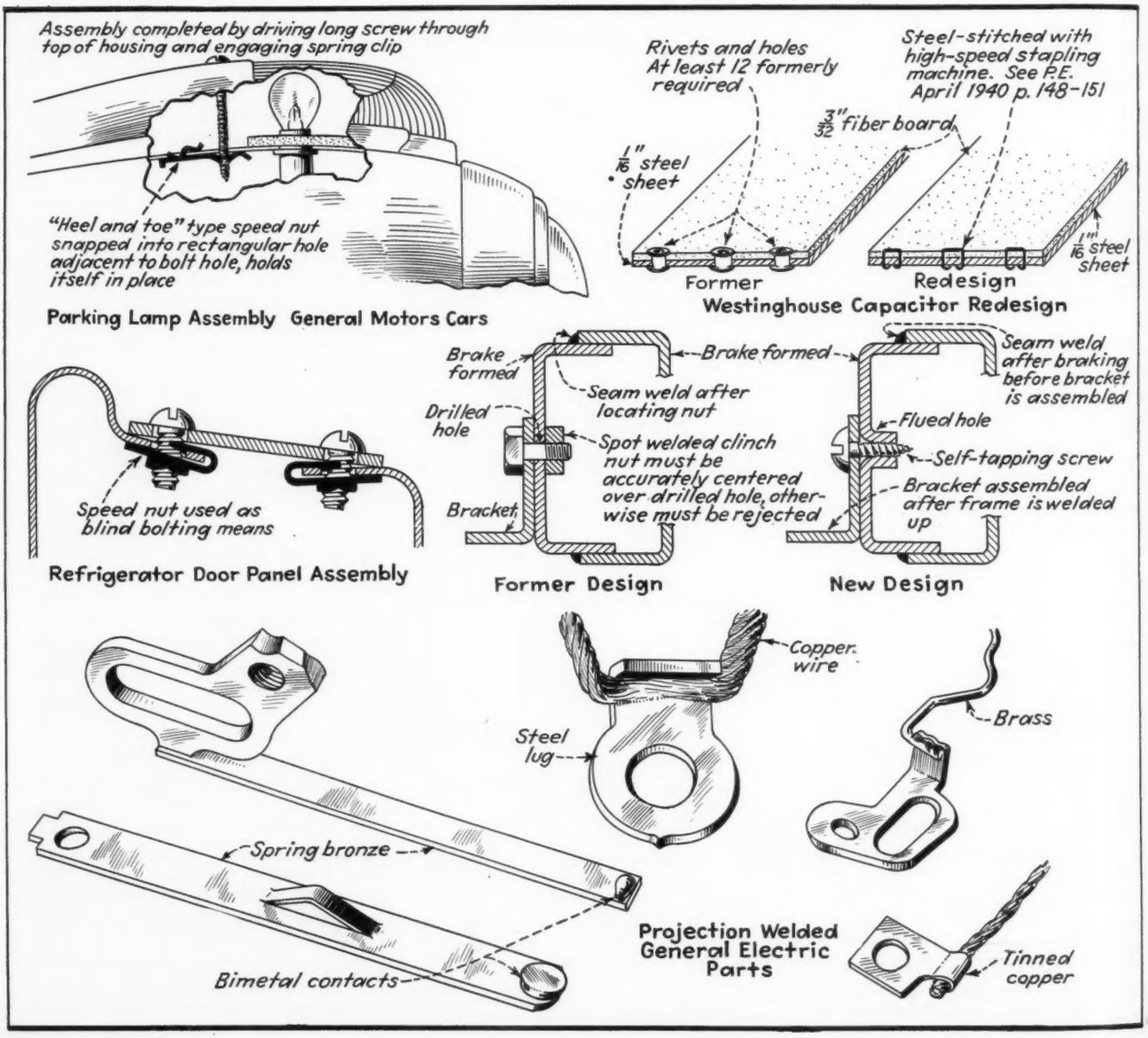


Center-to-center distance between crankshaft and camshaft of large engine was difficult to lay out and machine to the accuracy of 0.003 in. required for gear drive. This machining expense was eliminated by the chain-drive design shown at left, which permitted tolerances of as high as 0.050 in. for the center-to-center dimension. Idler sprocket for take-up of chain slack is mounted on an eccentric bushing. For small engines or large-quantity orders, proper tooling-up will give desired accuracy for gears with little trouble. Example of this is in automobile engines where machining is done in accurate high-production set-ups, and where simpler gears can be used.

FASTENINGS

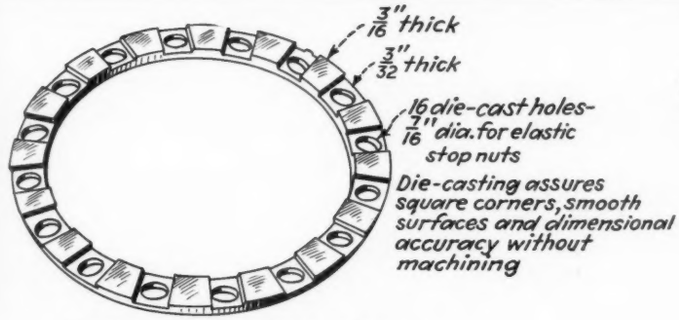
REDUCING ASSEMBLY TIME

Two major considerations govern the character of assembly method to be chosen. Is the assembly to be permanent or detachable, and what types of fastening are available for the construction and material being used? The chart at right gives some indication of methods available for fastening various types of materials. Typical designs of permanent and detachable fastenings, specially developed to reduce handling and assembly time, and illustrative of methods now being employed to speed assembly, are shown below. Numerous other examples will be found scattered throughout this number.

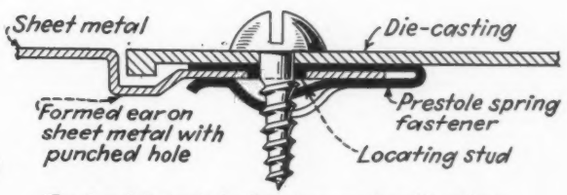

Assembly completed by driving long screw through top of housing and engaging spring clip
"Heel and toe" type speed nut snapped into rectangular hole adjacent to bolt hole, holds itself in place
Parking Lamp Assembly General Motors Cars
Rivets and holes At least 12 formerly required
Steel-stitched with high-speed stapling machine. See P.E. April 1940 p. 148-151
3/32" fiber board
1/16" steel sheet
Former
Redesign
1/16" steel sheet
Westinghouse Capacitor Redesign
Speed nut used as blind bolting means
Refrigerator Door Panel Assembly
Brake formed
Seam weld after locating nut
Drilled hole
Spot welded clinch nut must be accurately centered over drilled hole, otherwise must be rejected
Bracket
Former Design
Brake formed
Seam weld after braking before bracket is assembled
Flued hole
Self-tapping screw
Bracket assembled after frame is welded up
New Design
Copper wire
Steel lug
Brass
Spring bronze
Bimetal contacts
Projection Welded General Electric Parts
Tinned copper

FASTENING METHODS AND TYPICAL APPLICATIONS

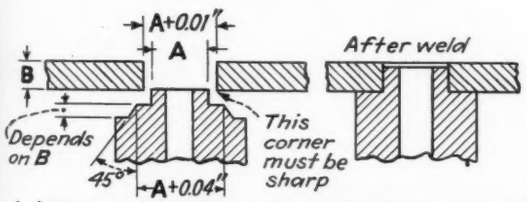
	Permanent												Detachable				
	Welding, Hammer Forged	Brazing, Soldering	Riveting	Steel Stitching and Stapling	Clinching or Crimping	Shrink Fits	Die Casting	Cast-in or Molded in	Cements	Vulcanization	Fused Thermoplastic	Nails	Bolts, Nuts, Screws	Patented Screws	Friction Fit	Spring Clips	Threaded Joint
Metal to Metal	X	X	X	X	X	X	X	X	X				X	X	X	X	X
Metal to Rubber				X	X					X					X		X
Fabric			X	X			X		X				X	X		X	
Wood			X		X				X			X	X	X	X	X	X
Paper				X					X			X	X	X		X	
Plastics			X		X	X		X	X		X		X	X	X	X	X
Plastics to Plastics			X			X			X		X		X	X	X	X	X
Metal			X		X	X		X	X		X		X	X	X	X	X
Wood to Wood			X	X					X		X	X	X	X	X	X	X


3/16" thick
3/32" thick
16 die-cast holes-7/16" dia. for elastic stop nuts
Die-casting assures square corners, smooth surfaces and dimensional accuracy without machining

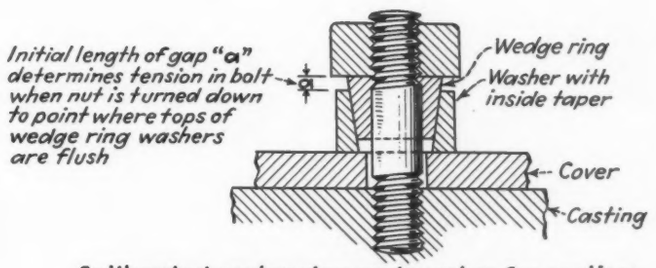
Aircraft Assembly Method



Typical Prestole Fastener Application

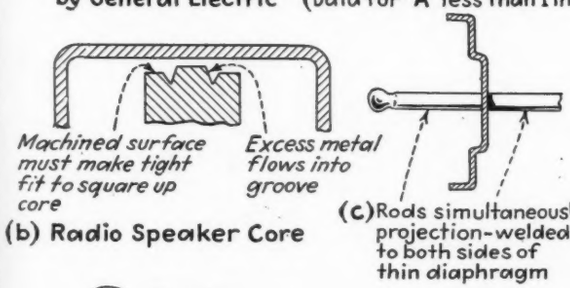


(a) Taper-Step Projection Welding as Practiced by General Electric (Data for "A" less than 1 in.)


Initial length of gap "a" determines tension in bolt when nut is turned down to point where tops of wedge ring washers are flush
a
Wedge ring
Washer with inside taper
Cover
Casting

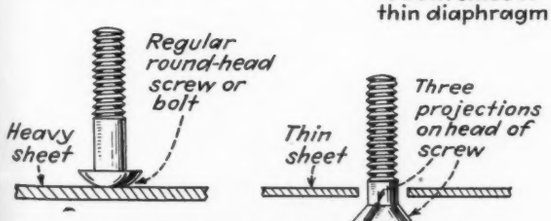
Calibrated wedge ring and washer for applications such as turbine covers and Diesels where equal equal tension in all bolts is important

Patent No. 2,188,356

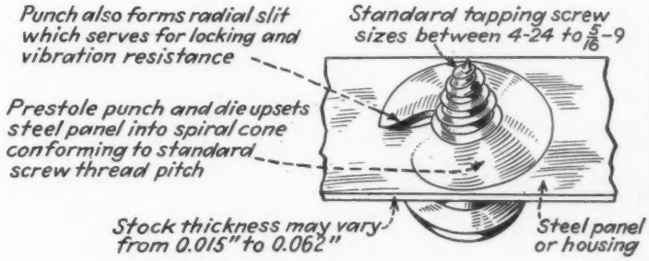


(b) Radio Speaker Core

(c) Rods simultaneously projection-welded to both sides of thin diaphragm

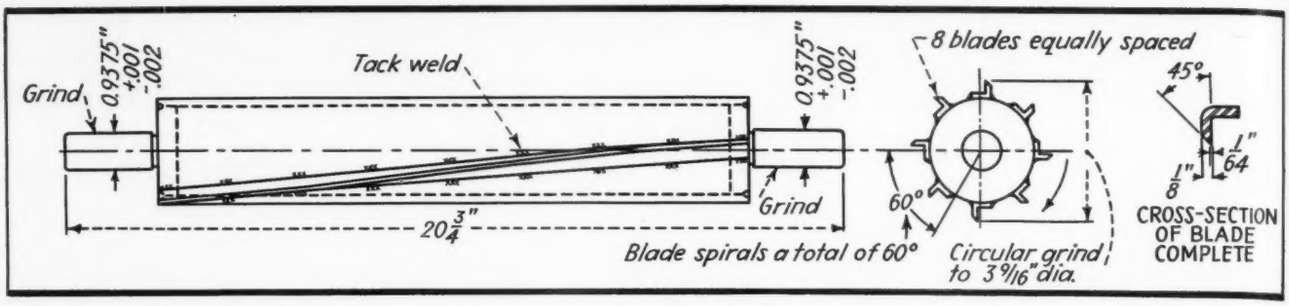


(d) Welding Fastening Screw to Sheet


Punch also forms radial slit which serves for locking and vibration resistance
Standard tapping screw sizes between 4-24 to 5/16-9
Prestole punch and die upsets steel panel into spiral cone conforming to standard screw thread pitch
Stock thickness may vary from 0.015" to 0.062"
Steel panel or housing

Integral Spring Fastener Formed with Punch and Die

Designs for Assembling Rotor Units

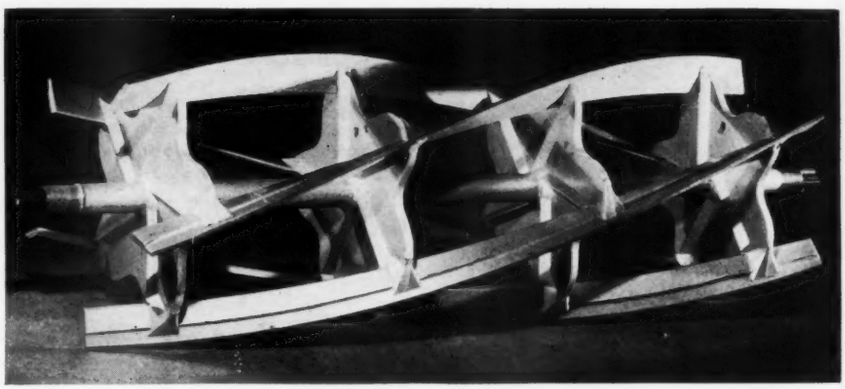


Rotary ice flaker with parts of different materials assembled by welding reduces materials costs and machining time. Steel stub shafts are welded into the ends of a piece of steel pipe, after which the outside diameter of the pipe is turned to obtain a true surface. Stainless steel blades, which have been formed on a press brake from flat stock and then twisted spirally to fit the pipe, are arc welded to the pipe. During welding the blades are held in a fixture.

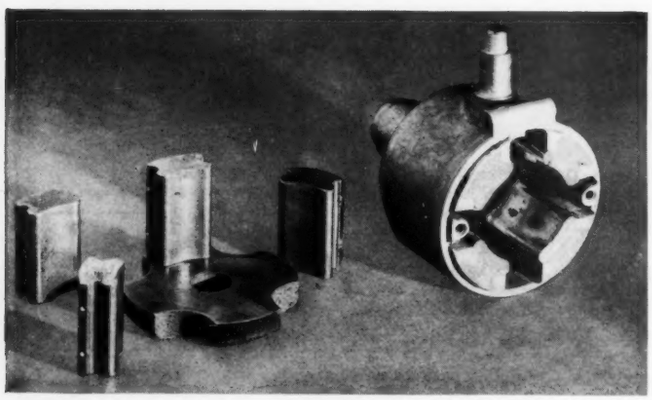
The assembled rotor is then dipped in a pure tin bath to protect the steel parts against corrosion, after which the blades are circle ground to final diameter and the stub shafts trued. Cutter is then set up in a milling machine and the edges of the blades bevelled.

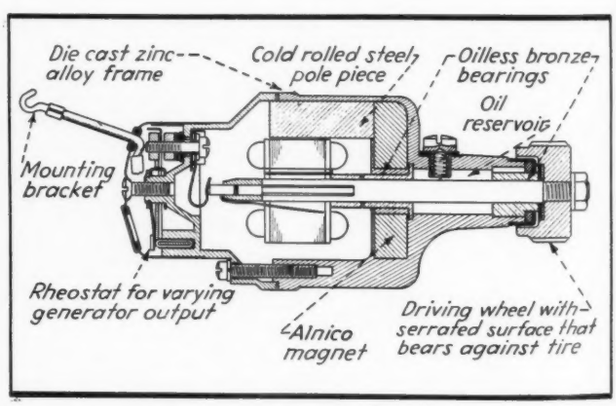
Cutter is made by York Ice Machinery Corporation and is used in their Flakice machine to remove ice in flake form from a rotating polished stainless steel refrigerant evaporator, the cutter being rotated by the advancing layer of ice on the evaporator drum. The blades are fabricated of stainless steel since they are continually exposed to moisture and their cutting edges must stay clean, sharp and rust-free.

Rotor for lawn mower assembled in die-casting operation eliminates operations involved in riveting blades to spider, as well as in machining spiders to fit shaft and subsequent press fitting. High carbon forged steel blades, and the tubular shafts are placed in the casting mold as inserts, after which four web sections or spider arms of zinc alloy are integrally die-cast in place, thus assembling the blades to the shaft. The zinc alloy spiders are rustless and add a finished appearance.



Generator Parts Assembled as Inserts



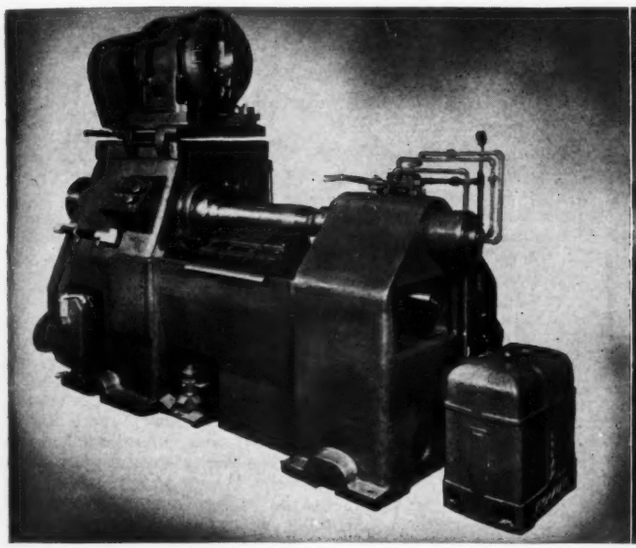

Die cast zinc-alloy frame
Cold rolled steel pole piece
Oilless bronze bearings
Oil reservoir
Mounting bracket
Rheostat for varying generator output
Alnico magnet
Driving wheel with serrated surface that bears against tire

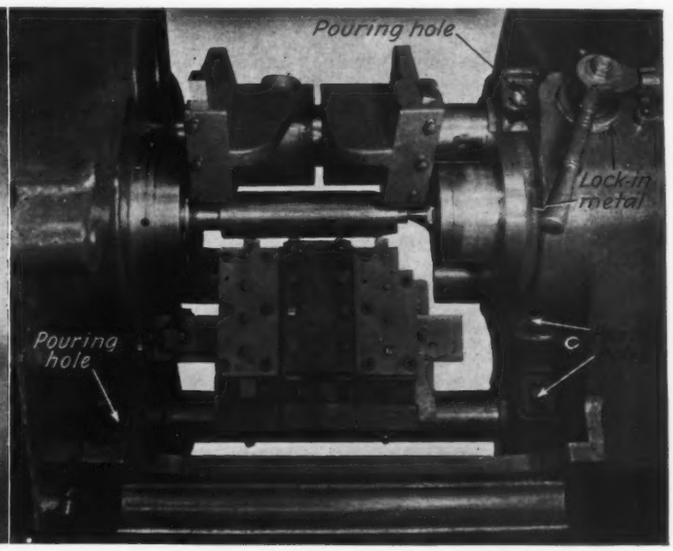
Compact design eliminates facing, drilling, tapping and riveting operations by using die-cast assembly method. Four stator pole pieces made of cold rolled steel, an Alnico magnet disk, a steel stud for holding the generator to a bracket support, and an oilless bronze bushing are all machined to size. They are then placed in a die as inserts and a zinc-alloy die-cast around them. The shrinkage of metal, while solidifying anchors the parts in place.

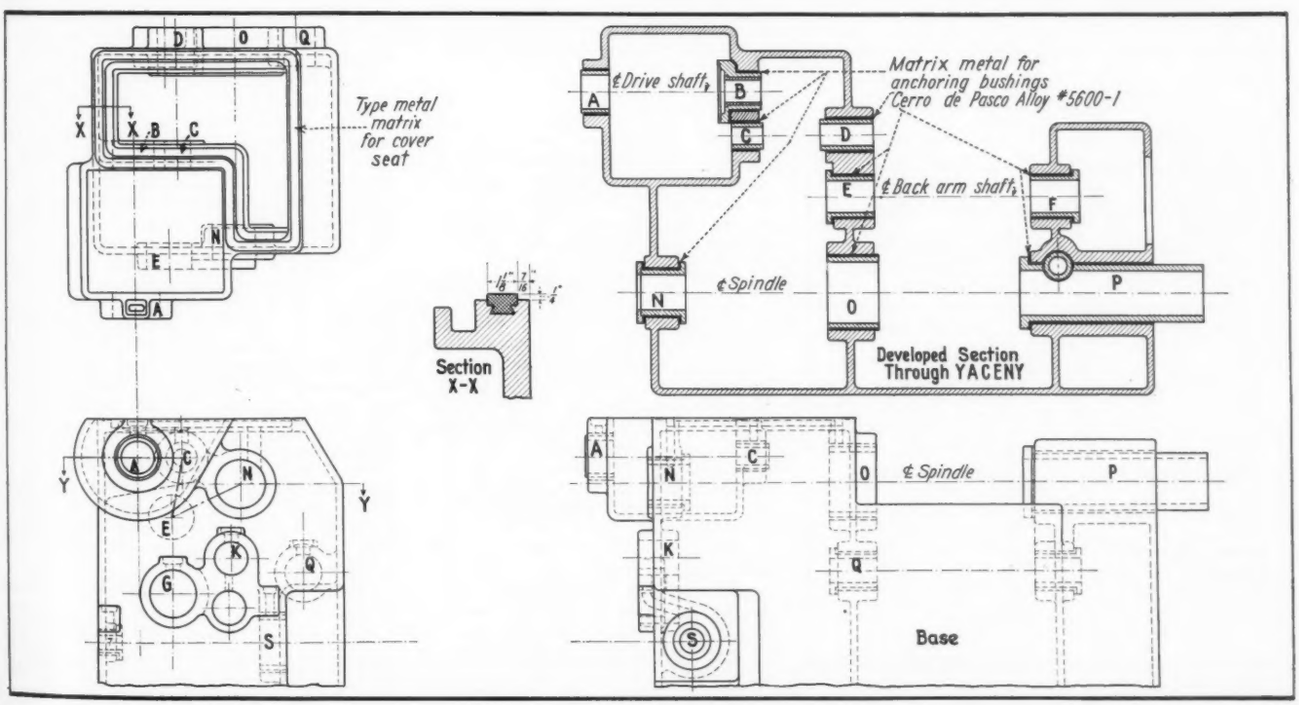
Bearings Anchored in Cored Holes

Machining and assembling time has been reduced to a minimum in construction of shell turning machines, by employing low melting point alloy to anchor shaft bushings and sleeves in cored holes. Bushings are aligned and supported in the cored holes of machine frame during assembly on pilot bars held in a fixture, while a lead-tin, high-bismuth alloy, developed by the Cerro de Pasco Company, is poured into the space between the bushing and hole. Pouring is done through holes cast in the machine frame. Except for ball thrust bearings on the spindle and also on the feed drum shaft, all shafts run in plain bronze bearings, having a lining of babbitt metal about 0.030 in. thick.

Further time is also saved by using type metal matrix alloy to form the seat for the combination coverplate and motor base. Here, the metal is poured in a trough cast in top of the headstock portion of the frame casting and allowed to find a natural level. All doors and plates are attached to the rough base casting by capscrews. Neoprene gaskets are used at doors and plates to insure oil-tight joints. A description of the feed drive arrangement for these machines is presented on page 201 of this issue. The shell machines were designed for quantity production. The National Machine Tool Builders' Association sponsored the development of the lathe and the work of designing it was done under the direct supervision of Myron S. Curtis, consulting engineer.







FINISHES

DRYING FINISHES FASTER

Considerable savings in production time have been made with near infra-red energy for finish baking, using compact lamp tunnels automatically operated. Process and applications were discussed in PRODUCT ENGINEERING, *July 1940, pages 307–310.*

Scope and limitations and production cost data on this type of drying, briefed below, are recent commercial installations. This material was furnished through courtesy of Fostoria Pressed Steel Company. A chart of typical applications based on investigations of the Commonwealth Edison Company appears on the following page.

INFRA-RED APPLICATION DATA

SUITABLE FOR — Mass production of many pieces of same size and shape. Simple shapes with all painted surfaces exposed to rays.

UNSUITABLE FOR — Few pieces varying in size and shape. Complex pieces with painted surfaces which are hidden from rays or shadowed by projection.

Hardening Characteristics of Finishing Materials

MATERIAL	BAKING TEMPERATURE	COMMENT
Synthetic enamels: Alkyd synthetic and urea-formaldehyde modified synthetics	250–350 deg. F. (1.75–2.0 watts per sq.in). 350–400 deg. F. (about 2.8 watts per sq.in.)	Harden by polymerization and/or oxidation. Oil modified resin is used as the vehicle. Response to infra-red treatment depends on pigments and color
Lacquers	100–150 deg. F.	Harden by evaporation. Since they are dried at low temperature to avoid pinholing and bubbling no discoloration will occur. Formerly air dried because of the low temperatures
Wrinkle finishes	150–450 deg. F.	More difficult to bake out because of the high temperatures required and/or time required for oxidation
Japans		Baking japans have not proved economical for this method of drying as the vegetable oils which they contain harden too slowly. Air-drying japans offer no difficulty

Operating Costs

No stand-by losses are incurred when the near infra-red process is used. Since the lamp source delivers energy immediately to the product, the equipment need not be put into service until the painted parts are prepared. When the processing is complete, the radiant energy tunnel may be switched off. Radiant energy tunnels need not be preheated before materials can be processed. Thus, another expensive operating charge is eliminated. One manufacturer of ranges and hot water heaters saved $200 per month on the cost of industrial finishes; finishing rejects were greatly reduced. Another, making stapling machines for industrial and commercial uses, states that radiant energy has saved 25 percent on kilowatt-hour consumption. A switch manufacturer estimates that in three months he will have paid for his installation with the savings effected along the production line. Formerly four men were required to produce with conventional equipment what one man now produces with radiant energy. The near infra-red process costs 52 cents per hour, when it is in operation during the processing period of the day. The conventional equipment must be in continuous operation, even though parts for processing may slow down due to delivery from the paint line, and costs 61 cents per hour.

In many cases radiant energy will accomplish the baking, or drying job in a shorter time. Often these savings in time are as much as 75 percent and 80 percent. One large manufacturer of commercial business machines formerly used steam ovens to process the finish. The overall length of this oven was 100 ft. Using radiant energy, the overall length of the tunnel was only 30 ft. thereby freeing 70 ft. of floor space which could be converted to other uses.

Applications of Radiant Energy Heating*

Operation	Material	Size in In.	Finish	Total Watts	Reflector Dia. and Spacing In.	Reflector Finish	Distance in In. of Filament From Work	Time Under Lamps	Watts/Sq. In. on Work
Wrinkled finish on camers	Aluminum die-cast metal	2x4x6	Synthetic plastic wrinkle finish sprayed on	1000	8¼ dia. 9½ spacing	Alzak	8	6 min.	2.75
Drying out inside of metal caskets	Sheet steel pressed and welded burial caskets	16x24x72 approx.	Plated or oxidized surfaces from which moisture must be removed on inside	2600	None — special arrangement	None	3 to 8	5–10 min.	0.40
Enamel baking on small metal stampings	Sheet metal display with pressed pocket for advertising	4x6x1/32	Red enamel sprayed on	4160	8¼ dia. 8½ spacing	Alzak	12	12–15 min.	1.33
Removing cyanide from pits and pores in castings	Gray cast iron	10–14 dia. 1½x2 height	Plating after wash in cyanide and hot water	6240	8¼ dia. 8½ spacing	Alzak	7 varied	20 min.	3.2
Baking finish on transformer cases	Pressed sheet steel boxes (22 gage)	3x3x4	Black nitro-cellulose lacquer with solvent—5 min. air dry, 10 min. under lamps, 10 min. air	7800	10 dia. 12 spacing	Gold	8	10 min.	3.50
Drying adhesive lacquer or glue on speaker cones	Steel frame and paper cones	6 dia. cones 3 height speaker	Nitro-cellulose adhesive lacquer	22,880	7½ and 9¼ dia. 7½ and 9¼ spacing	Gold and Color Alumilited	8	Continuous 2 ft. per min.	2.40
Laboratory use, baking finishes on cans	Tin cans, labels and decoration printed directly on tin	2–3 dia. 4–5 height	Enamels, lacquers, inks	780	9¼ dia. 9¼ spacing	Gold	Not known		Varied
Baking enamel finish on globe valves	Cast or wrought iron and brass	Up to 1½ valves	Green air dry enamel	2080	8¼ dia. 8½ spacing	Alzak	6–8	5 min.	2.75
Baking wrinkled finish on die-cast auto heater cases or frames	Die-cast frame or case for auto hot water heater	10–12 dia. 4½ height	Wrinkled finish enamel—grayish tan color—wrinkle formed in 3 min.	8320	8¼ dia. 8½ spacing	Alzak	10–12	9 min.	3.7
Baking enamel on molded bakelite radio cabinets	Small portable radio cabinet of molded bakelite—mottled brown color	6x8x14 ⅛–½ thick	Urea formaldehyde baking (220 F.) cream color	8320	8¼ dia. 8½ spacing	Alzak	8–12	9 min.	3.7
Baking synthetic urea formaldehyde enamel on metal	Test samples of steel sheet	3x6 (18 gage)	Synthetic enamel, urea formaldehyde, air-dry enamel—Chinawood, soya and meleic oils	2080	8¼ dia. 8½ spacing	Alzak	12	7 min.	1.8
Drying ground coat preparatory to firing on at high temperature	Steel sheet	12x12 20 gage	Water solvent ground coat gray color	6240	8¼ dia. 8½ spacing	Alzak	10	9 min.	2.6
Drying first finish coat on fired ground coat	Steel pan with vitreous ground coat fired on	7x15x4½ deep — 20 gage	Water solvent white first finish coat	6240	8¼ dia. 8½ spacing	Alzak	10	5 min.	2.6
Baking synthetic enamels on small axe blades	Steel axe blades	3x5¾ blade edge to ¾	Gloss black synthetic enamel and thinner	2080	8¼ dia. 8½ spacing	Alzak	12	15 min.	2.2

* *From investigations of radiant energy heat made by the Commonwealth Edison Company*

Plastic Coatings Speed Finishing

Quick-drying durable plastic coatings, both air and heat setting, can now be formulated. Recently developed dispersion resins reduce drying time to five minutes or less in some formulations. Acetate and acetate-butyrate flake, and urea resins all lend themselves to quick-finish formulations. Application may be by brush, spray or dip. Melamine resins, a recent development, produce a hard, abrasion-resistant glossy finish at lower baking temperatures. Vinyl resins can be compounded for application as corrosion-resistant liners for beverage cans and tank cars, for coating metal caps and closures and for coating lithographed metal surfaces. Vinyl resins can also be used as stop-off coats in electroplating processes.

FINISHES THAT DRY IN MINUTES, yet provide good surface protection, have been made possible through the development of dispersion resins. The term dispersion resin describes one of a group of materials regarded as "precured" coatings. They are soluble only in part in varnish solvents, but may be dispersed readily in the aromatic hydrocarbons. Upon being laid down in a film, drying takes place by the evaporation of the thinner, thus making "drying time" a matter of the formulator's choice. Quick drying coatings have long been in use, but it was not until the development of these Bakelite dispersion resins that immediate drying was obtainable in a durable coating which can be re-coated within a few minutes with a wide variety of materials, without "lifting" or softening of first coat. Rapidity of dry is of special importance in the manufacture of products from lightweight aluminum and magnesium alloys, where severe baking temperatures would be destructive. Dispersion resin coatings cannot be easily formulated to more than a semi-gloss or eggshell finish, but dull, durable, fast-drying coatings can be made up readily for applications such as camouflage work where it is necessary to change colors quickly.

Typical Applications

Ten minute air-drying undercoats, which withstand 6 months salt spray test

Aircraft primers that air-dry to recoat in 5 minutes

Ten-minute enamels for spraying or tumbling to produce a complete finish in a single coat

Tanks and ordnance requiring successive coats of camouflage without undercoat lifting or softening.

NEW HEAT-REACTIVE, OXYGEN-CONVERTIBLE RESINS (based on Carbic anhydride), for use with linseed oil formulations, provide good color retention and produce brilliant whites and delicate pastels that retain their original clarity of tone. They also dry rapidly, setting within one hour and drying to a porcelain-like surface overnight. These resins also accelerate the bodying rate of linseed oil formulations. Their relatively low hardening temperature is an additional safeguard against darkening of color.

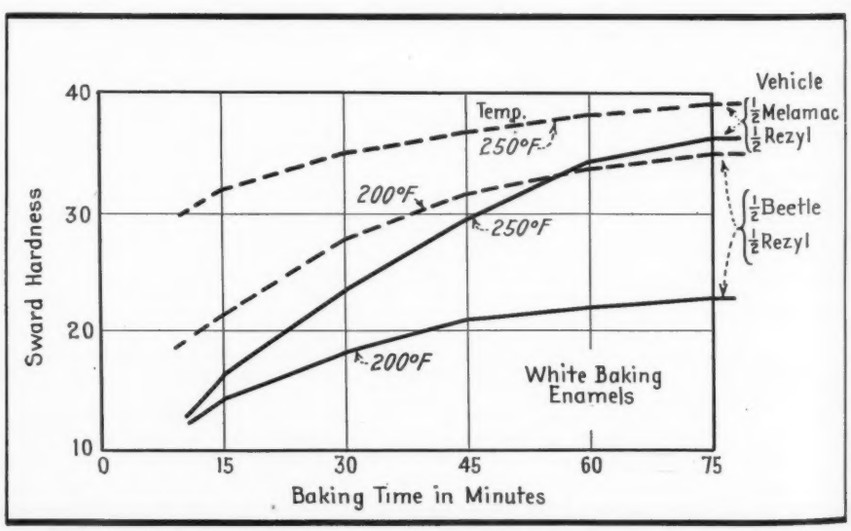
CRIMPED OVER AFTER COATING. Lithographed metal panels, coated with a vinyl resin and baked in the flat, are stamped out to form coasters. After stamping, the edges are crimped around one and one-half turns on less than $\frac{1}{8}$ in. radius to form a side wall. Coated surface is unmarred after this forming.

LAMINATING FILMS of vinyl resin can be rapidly applied to flat sheets, radio and instrument dials or flat navigation instruments by placing the part and the thin resin film under highly polished chrome-plated platens under heat and pressure. This produces an abrasion-resistant transparent surface, impervious to moisture, acids and alkalis.

GOOD STABILITY under ultraviolet light, and good weather resistance are outstanding properties of a new finish formulation based on cellulose acetate butyrate. The lacquer is applied by brush, spray or dip. It was developed by Flood & Conklin in cooperation with Hercules Powder chemists.

REDUCTION IN BAKING time, made possible by melamine resins, also speeds production of hard, white finishes. Resins made from melamine, now commercially available are, like the urea resins, of the thermo-setting type. Supplied as solutions in organic solvents, they are used for baking enamels in combination with alkyd resins and can be baked at relatively low temperatures obtaining the speed and hardness formerly secured only with high bakes. Urea resin vehicles meeting the usual requirements for white enamels, are generally baked in the range of 250 deg. to 325 deg. F. Similar enamels based on Melamac resin may be baked satisfactorily at 180 to 225 deg. F. producing films of excellent hardness and gloss, resistant to humidity, chemicals and heat.

The accompanying curves show the hardening effect, in white enamels, on an oxidizing type alkyd resin mixed in one case with an equal quantity of urea resin and in another with an equal quantity of melamine resin partially



Relative hardening effect of urea and melamine resins on alkyd resin enamel

plasticized with alkyd. The melamine combination bakes hard in 45 min. at 200 deg. F., while both the straight alkyd and the urea-alkyd mixture remain relatively soft after 1¼ hr. at 200 deg. F. In an hour bake at 250 deg. F. the urea resin enamel reaches the same hardness as the melamine resin enamel attains in the same time at 200 deg. F. On the other hand, if the melamine resin enamel is baked at 250 deg. F., it reaches in 30 min. the same hardness for which the urea resin enamel requires a bake of over an hour at the same temperature.

Another way to take advantage of the speed and hardness of the melamine resins is to use them with larger proportions of alkyd resin than would be used with urea resin, with consequent economies in formulation. In an hour's bake at 250 deg. F. the hardness of an enamel containing 35 percent urea resin is substantially the same as that attained with only 20 percent of a melamine-urea combination mixed with the same oxidizing type alkyd.

Considerable improvement in heat resistance can be effected by the addition of urea resin to alkyd types. Such combinations in white enamels yield excellent results when baked at temperatures up to 325 deg., but rapidly lose both gloss and color when subjected to higher temperatures.

Some of the Melamac resins when used with the heat-resistant Rezyl resins, retain both gloss and color on prolonged exposure to temperatures as high as 425 deg. F. Such enamels, usually over an alkyd primer, can be used for stove parts and electrical appliances, for which vitreous enamel or metal plating have formerly been considered necessary. Enamels made from these new resins are more resistant than comparable types based on urea resins, not only to elevated temperatures but also to chalking on outdoor exposure. They are less readily affected by high humidity or grease.

Polishing Stainless Steel Electrolytically

1. Process

Consists of immersing parts to be polished in an electroplating bath with the parts as anodes. Various electrolytes, covered by patents, have been developed for polishing stainless steel.

2. Character of Finish

With dense rolled or drawn surfaces, the parts come from the bath with bright mirror-like finish.

With rough cast or forged surfaces, the process brightens all parts of surface but does not fill-in or smooth off surface irregularities except to remove a thin layer of the surface defects.

To bring out the finish on deep parts formed from sheet or strip, it is necessary to use special cathodes shaped to conform with the cavity of the part.

3. Advantages

As compared with buffing, the process eliminates danger of scoring or burning the work, and also of warping flat surfaces.

Process removes discoloration and oxide scale formed by spot welding. The process makes obvious defects such as pit-marks, scratches, abrasions, and drawn surface marks, which can then be removed by buffing and polishing on a wheel.

4. Applications

Improving appearance of rough forgings and castings.

Polishing small parts or wire parts, which are difficult to hold.

Polishing intricate parts that have recesses which cannot be reached by buffing and polishing wheels.

New Finishes for Special Purposes

A WHITE ENAMEL has been developed that has excellent color retention under high heat and is resistant to hot oil and greases. Its special field of usefulness is on stoves.

HIGH GLOSS, semi-gloss, and wrinkle synthetic baking enamels have been especially developed for infra-red baking. These Raydur enamels bake under infra-red heat in 3 to 20 min. and can be handled for assembly a half hour later.

A NEW FINISH, called Hammertone, closely resembles beaten metal. It is supplied in copper, bronze, silver and other ornamental metallic colors.

PERSPIRATION-PROOF LACQUER especially suitable for finishing articles frequently handled, such as flashlamps, pencils, compacts and lip-stick holders has been developed. The lacquer resists corrosive action of perspiration and protects metal surfaces or enamel color coats.

NEW HIGH-SPEED GRAIN FINISH for the rapid application of wood grain on metals consists of a quick-drying Durad Speed primer, which receives the graining ink, and a top coat of air-drying or quick-baking clear lacquer.

CHLORINATED-RUBBER-BASE ENAMELS air-dry dust-free in a few minutes. Under normal application conditions, they can be freely handled in twelve hr. and will not "paper print." Adhesion and weather resistance are good; flexibility improves with age. These Neoprene enamels are for use on metal products, and on wood with a surfacer to provide an opaque finish or without surfacer to show grain.

SPRAYED ALUMINUM is replacing two coats of black enamel for finishing air-cooled aircraft engine cylinders. In addition to speeding production, aluminum coat is more dependable, lasts longer. Aluminum cylinder finish is now specified for all Navy aircraft engines.

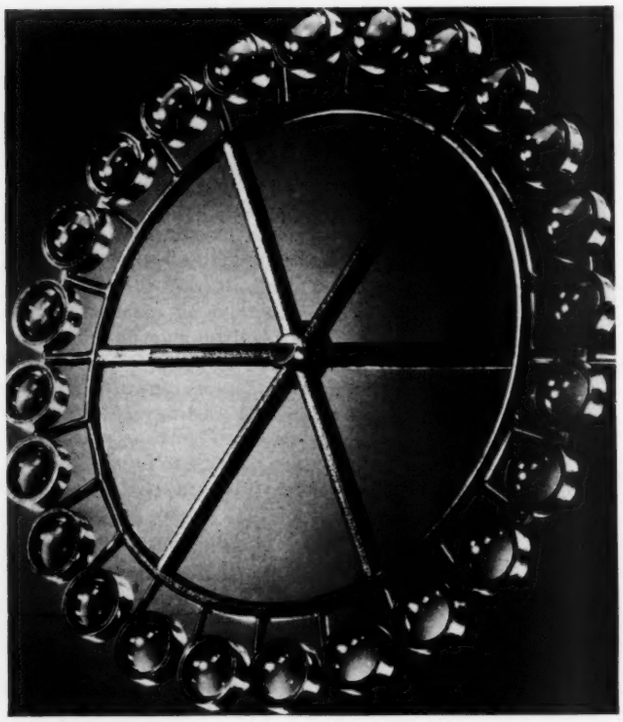
SATIN FINISH, applied with stiff fiber rotary brushes, eliminates expensive polishing operations on aluminum domes and hubs of aircraft propellers. High polish, demanded for sake of appearance by airlines, showed fingermarks and grease spots more readily and was unnecessary for fighting planes.

COLORED RIVETS, clips and small parts save time, help workers identify parts more readily and reduce errors in assembling. A new coloring and rust-proofing process makes available colors of bluish-green, dark red and jet black. Although process requires 10 percent more time for black and 20 percent more time for colors than conventional colorless rust-proofing, savings in assembling makes it worthwhile for certain jobs. Similarly, special lacquers and enamels have been developed for coloring shell and bomb parts to speed assembly.

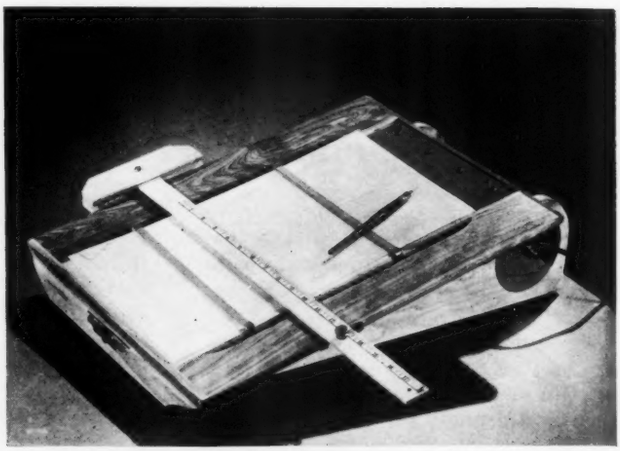
TWO TO FOUR TIMES AS FAST as present processes, a new high-speed brass-plating process developed by du Pont yields smooth bright deposits of controllable thicknesses at a rapid rate of deposition.

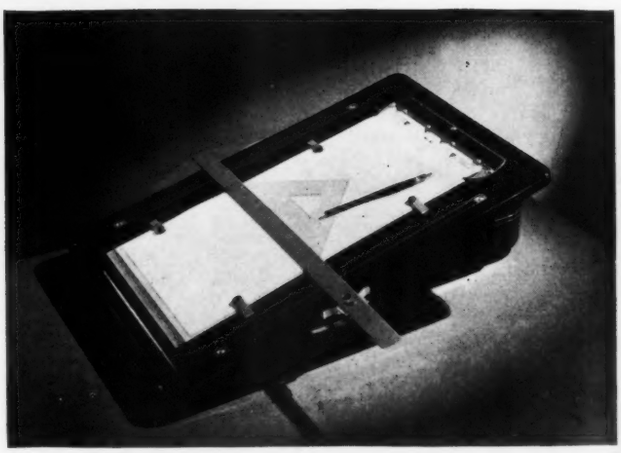
PLASTICS

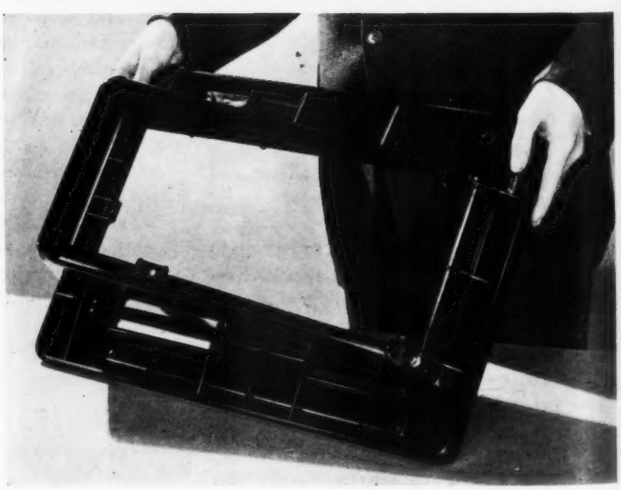
Designed for Speedy Assembly



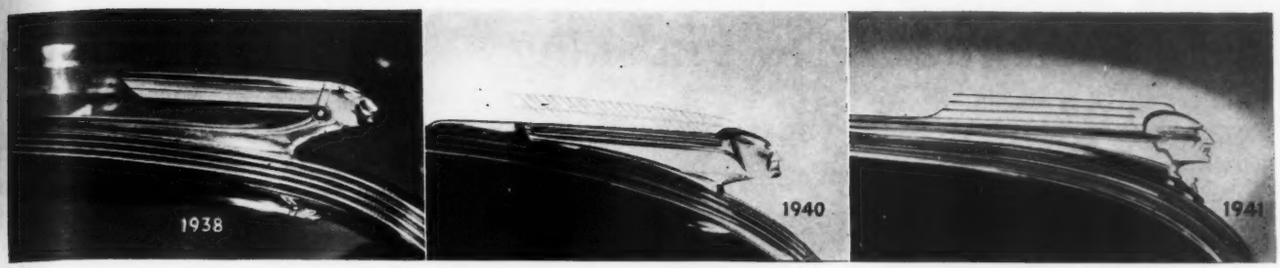
Plastic mounts are formed around 24 camera lenses during molding process in one injection shot; assembly of lenses into low-priced cameras is thus considerably speeded. The lens is anchored securely, formed and machined metal housings are not required. Costs are considerably reduced. No finishing other than removal of sprue is necessary.



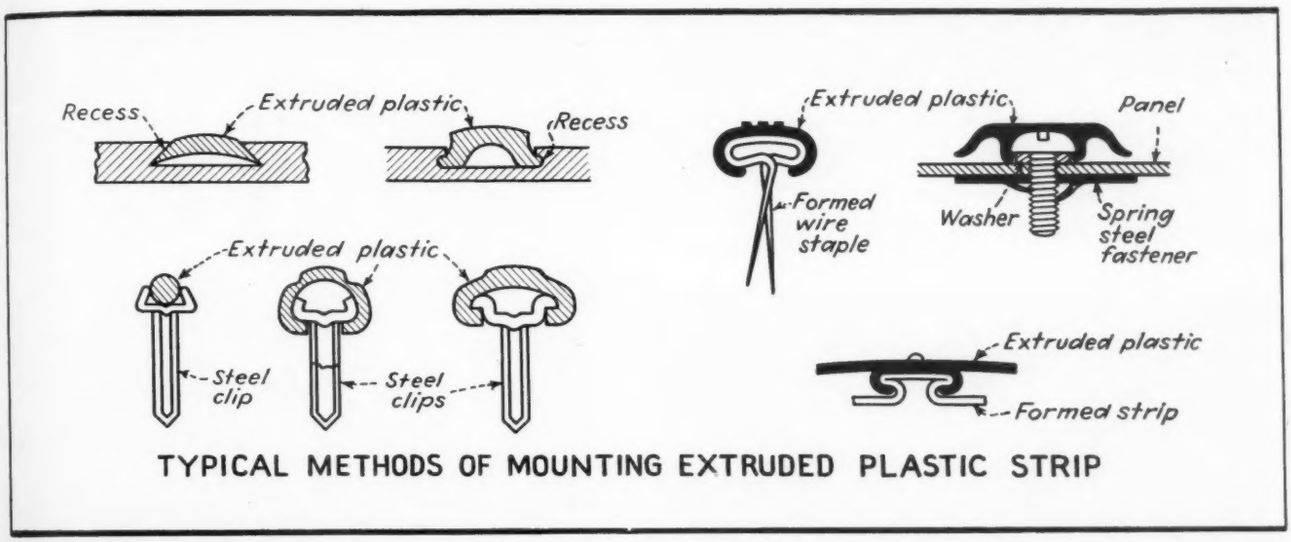




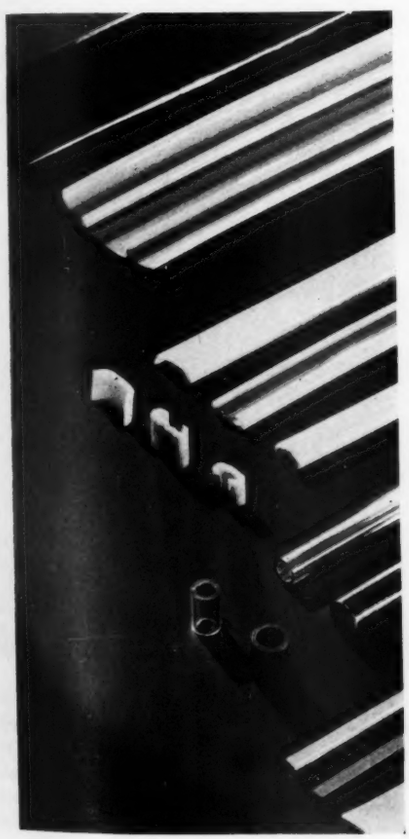
Simplified design and reduced production costs were obtained through the use of plastic for the new Speed-O-Scope drafting instrument of the Speed-O-Print Corporation. Design was formerly assembly of wooden parts, as shown to the right, above. The new plastic model is illustrated to the right, below. By molding the instrument in one piece, costs were considerably reduced. Only assembly required is to fasten the louvre section to the one-piece frame with spring latch clips. Since finish and color are inherent in the molded plastic, no sanding or coating is necessary. Molded of Bakelite phenolic by the Chicago Molded Products Corporation.



Three steps in a design change-over. Radiator ornament on the 1938 Pontiac was one-piece zinc die-casting, chrome-plated. In the 1940 Pontiac, the ornament was a combination of die-casting and molded Crystalite. The 1941 deluxe Torpedo fleet models have a one-piece Crystalite injection molding for radiator ornament.



TYPICAL METHODS OF MOUNTING EXTRUDED PLASTIC STRIP



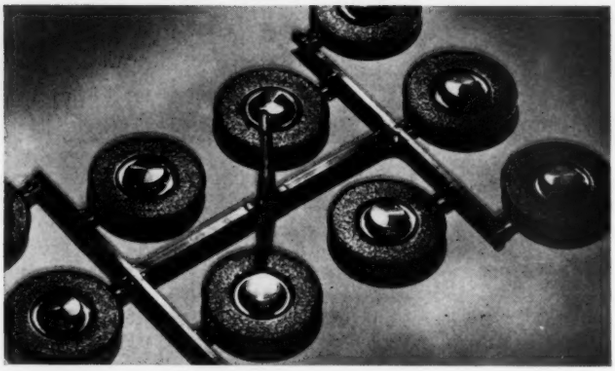
Extruded plastic is now available in wide variety of colors and in any length. Shape of plastic strip is determined by die used. No plating or finishing is required. Numerous methods are available for mounting, utilizing wire staples, formed metal strip, spring steel fasteners and the like. Usual plastic material for extrusion is cellulose-acetate or acetate-butyrate.

Molded phenolic, used for a two-piece lampbase, reduced machining time and eliminated metal-forming operations. In addition, designers found it possible to utilize the support as a housing for a five-tube radio. Material is inexpensive and light in weight. Designed by Mitchell Manufacturing Company and molded of Bakelite by Midwest Molders. Finish is sprayed on.

Plastics in Armaments

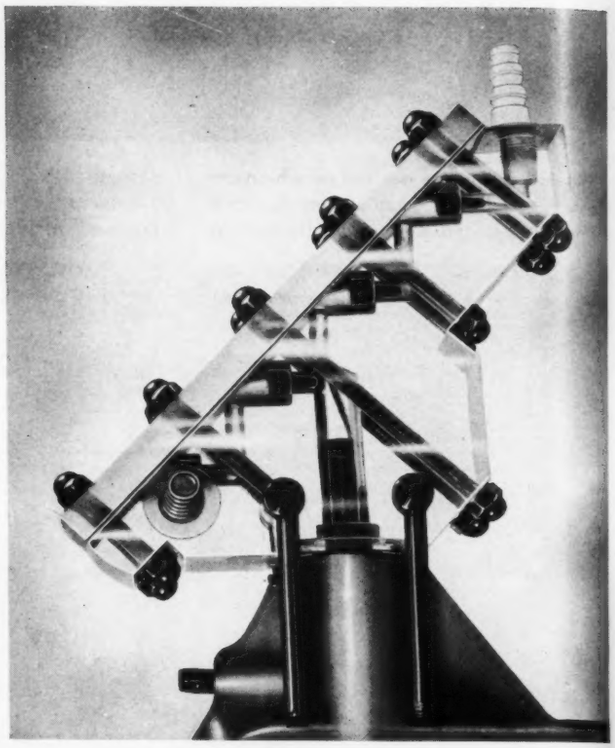
Molded plastics are being used in British armament production. Gun mounts sent to this country for study by U. S. Army engineers have handwheels of molded plastic. These parts were formerly die-cast or machined steel.

Less Weight and No Finishing

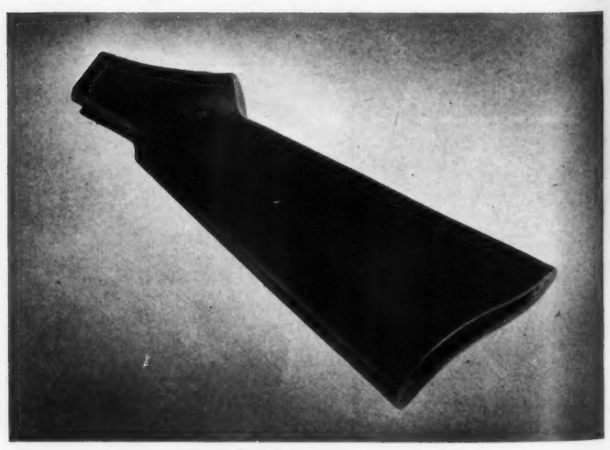


Imitation wrinkle finish is obtained directly in the molding operation by suitable die surfaces, in the production of plastic typewriter ribbon spool covers, which replace stamped metal covers on Underwood Elliot Fisher typewriters. Separate finishing operations are entirely eliminated. Part is injection-molded of Tenite by the Mason Company.

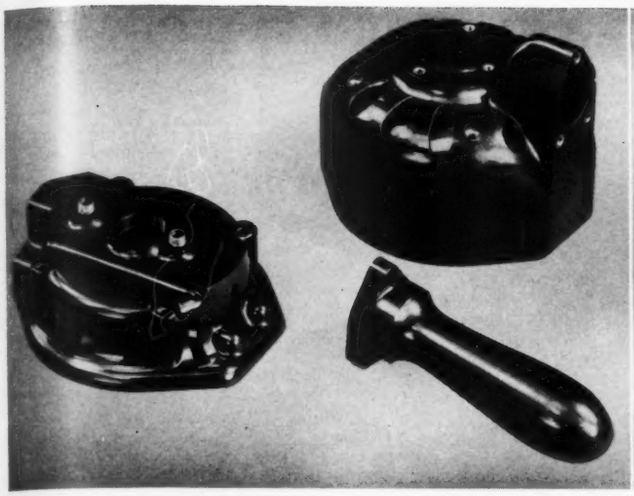
Finishing operations can often be eliminated by the use of plastics, as in the new plastic agitator developed by the Bakelite Corporation and the Eclipse Molded Products Corporation. Metal agitators require a special finish to resist solvents, although this finish is expensive, it is not always satisfactory. Additional time and cost is saved by integrally molding a spline in the agitator to replace a machined spline. In aluminum, agitator weighed 4½ lb.; in plastic it weighs 2¾ lb. Impact strength is equivalent to that of metal and plastic has greater resistance to caustics. Designed for Barton Corp.

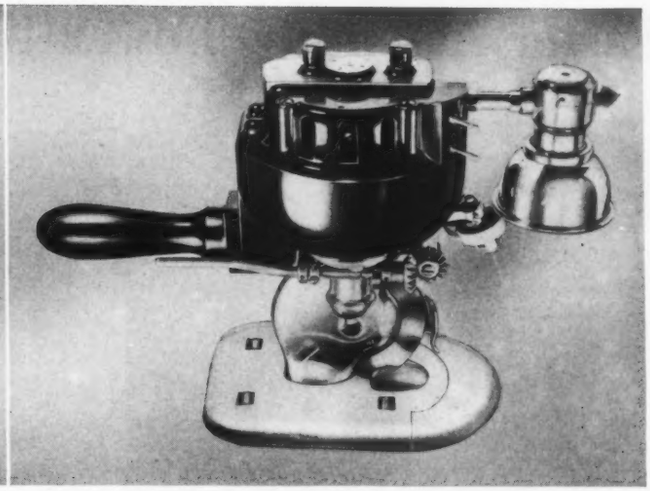


Savings in finishing and machining time through use of Plexiglas for a pump housing. Machined from a solid block with ordinary woodworking tools, the transparent housing permits visual inspection of pump operating parts. If metal had been used, some finishing means, or some special alloy metal, would have been required to provide acid resistance. The use of plastic offered no special advantages for assembly. The Plexiglas is tough enough so that it can be tapped like metal. Designed by Milton Roy.



Production costs were reduced through the use of transfer-molded Bakelite phenolic instead of high-grade walnut wood for machine gun stocks. Stock is hollow and light in weight, has good impact resistance and is moisture, wear and abrasion resistant. Guns are manufactured by Smith and Wesson; stocks are molded by the Shaw Insulator Company.



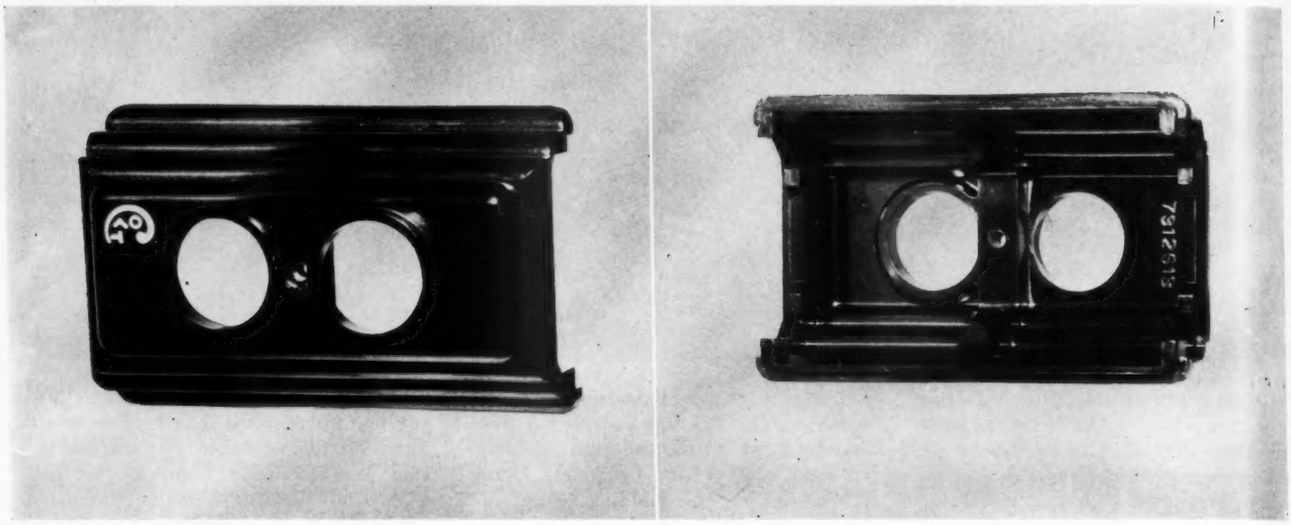


Finishing troubles, caused by deterioration of a baked enamel finish under heat developed in tool operation, were eliminated through redesign of the product for plastic molding. Machining required on the metal housing was also considerable. Plastics provided a permanent finish on the redesign; holding devices, and wiring channels were formed during the molding operation. Tapped inserts were molded in, machining operations were thus held to minimum. Molded of Bakelite by the Insulation Manufacturing Company for the U. S. Cloth Cutting Machine Company

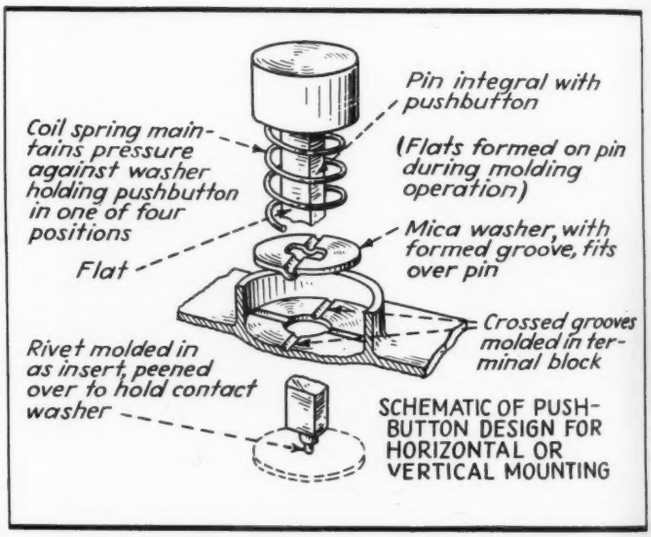
Longer service life is obtained through the use of plastic fish-net floats. Although wood floats cost 25 percent less, the wood loses buoyancy, and requires a preservative twice a year; hence cost is equal after approximately two years of service. Aluminum floats cost about 25 percent more. Since cork floats are imported, war conditions make them increasingly hard to obtain. Cork absorbs water, loses its buoyancy, and tends to slough off in service. Plastic floats, manufactured by J. H. Shepherd Son & Company, are 15 percent lighter than aluminum for the same buoyancy and being of comparatively softer material are less apt to damage the net twine. The plastic float costs 10 per cent more than cork.

Weight reduction by substitution of materials. Tri-Pak oil bottles are now injection-molded of Tenite II plastic, and are only 20 percent of the weight of the former glass containers. Since this is a west coast concern, there is a consequent saving of 9 percent in freight costs on shipments to the east. The label is printed on 0.005 in. gage Eastman acetate sheeting placed inside of the container and held in position with acetate cement. Permanence and visual depth are obtained. The improved appearance of the package has resulted in a considerable increase in sales; for the first three months of this year sales have exceeded total sales for 1939. The bottles are molded by the Remler Company.

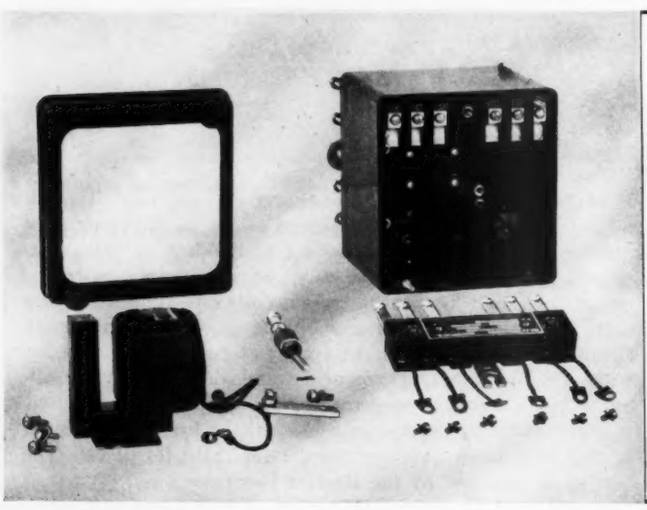
Faster Assembly, Lower Unit Cost

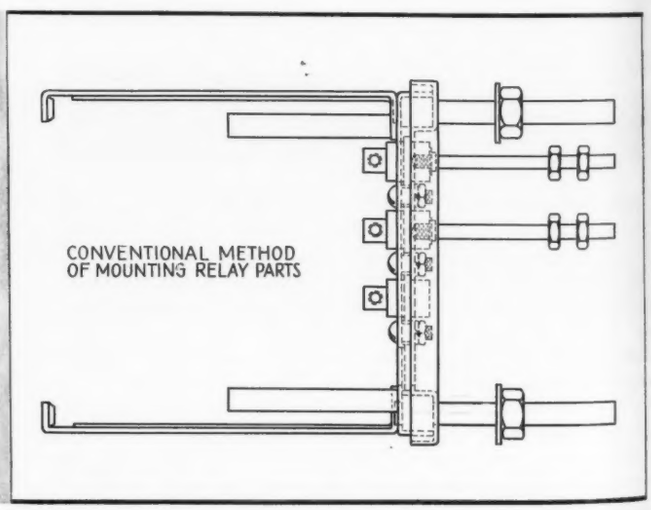


Phenolic molded plastic made possible a better and more attractive design, as compared with sheet steel, in this pushbutton station by Colt's Patent Fire Arms Mfg. Company. Electrical properties of the material permit smaller case dimensions without fibre insulation; while ample strength is easily assured by ribs. A bead around the edge not only adds strength but forms a rabbit joint with the metal base, while another bead forms a guard around the start button. The non-removable buttons are designed so they can be rotated to seat in any one of four positions for proper reading. See drawing, right.


Pin integral with pushbutton
Coil spring maintains pressure against washer holding pushbutton in one of four positions
(Flats formed on pin during molding operation)
Mica washer, with formed groove, fits over pin
Flat
Crossed grooves molded in terminal block
Rivet molded in as insert, peened over to hold contact washer
SCHEMATIC OF PUSH-BUTTON DESIGN FOR HORIZONTAL OR VERTICAL MOUNTING

Cost of assembling the brackets, contacts and insulating blocks in electrical relays often exceed cost of the parts. To simplify production and reduce unit cost of the relay, General Electric engineers specified the case to be molded phenolic with integral mountings for the terminal studs and fixed contacts and molded barriers between contacts. Housing also provides bearings for the armatures, a backstop mounting for the relay armature and molded-in inserts for pigtails.





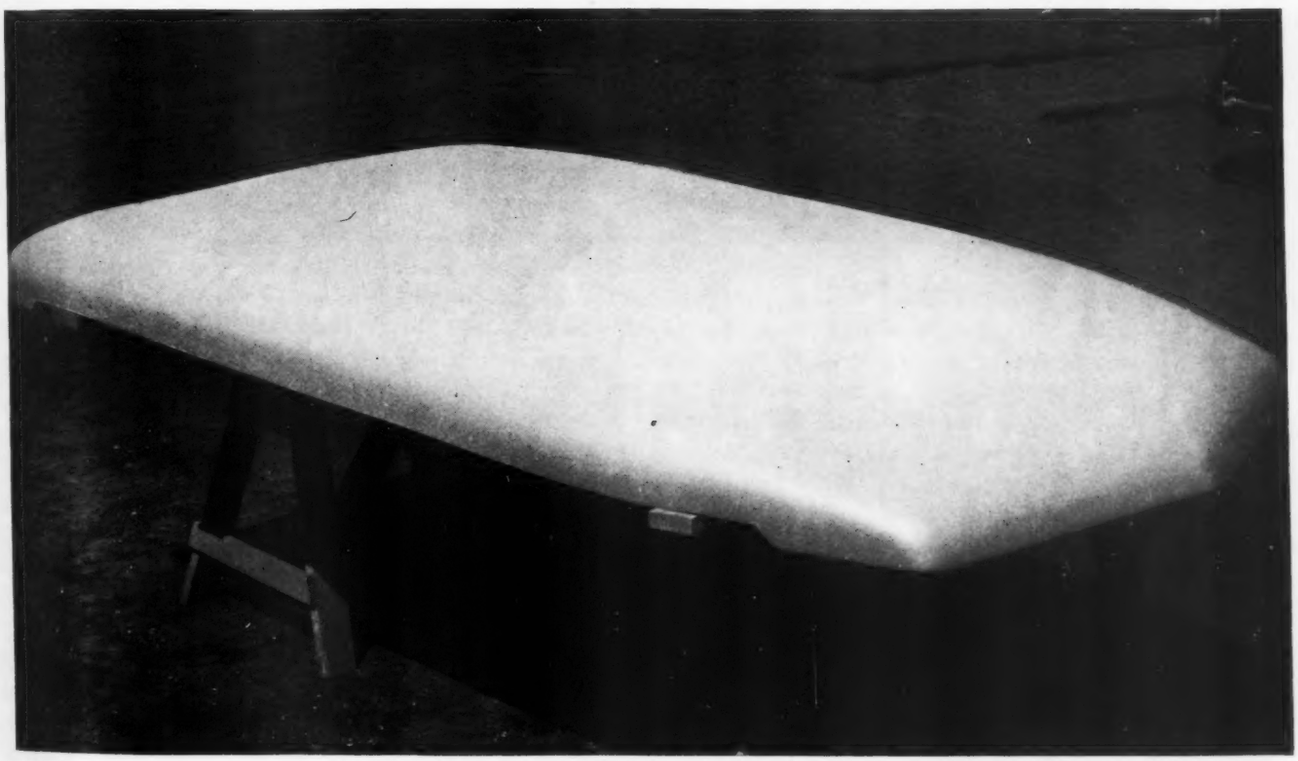
Laminated Plastic Construction

For fast fabrication of complex shapes, sub-assemblies and housings wherein high strength-weight ratios and low production cost are important factors, laminated plywood bonded with synthetic resin adhesives under heat and pressure is often the most desirable constructional material. With the present trend towards replacement of metal, where possible, in product design, and the progress being made in development of new resin adhesives and improved fabricating methods, this type of construction is being more and more used in the marine, automotive, aircraft, household appliance and similar fields. Data and illustrations for this article were furnished by Harold P. Moon of the Allied Aviation Corporation.

FUNDAMENTAL FABRICATING PRINCIPLE in present processes is use of deflated or inflated rubber bag as one-half of a pair of molding dies. This means savings in die cost: the die is wood and can be made by any good pattern maker, and no accurately machined mating die is required. The rubber bag pressure is substantially of the order of fluid pressure and at right angles to the work. In the Vidal process, widely used for aircraft and automotive work, the sub-assembly is inclosed in a rubber bag and the bag inclosed in a pressure tank which is filled with steam at 50 to 100 lb. pressure. Thus reinforcing structures can be molded to a part being formed, all in a single operation.

ADHESIVES can be of the thermosetting or thermoplastic type, depending on the process used. Generally, phenolics and ureas require relatively high steam temperatures and pressures and relatively long cures, although certain urea adhesives recently available cure under lower temperature and pressure. Of the thermoplastic types, polyvinyl acetates, which cure fast under relatively low steam temperatures, are particularly successful when used with Vidal equipment. Impregnation is about 40 percent by depth, and shear strengths of the order of 250 to 300 lb. per sq. in. can be obtained. Delicate control of heat and pressure is not required.

APPLICATIONS of laminated plywood are wide and varied. Among the more important uses are in marine construction, aircraft sub-assemblies, automotive bodies, engine cowlings, portable knock-down radio houses for army use, and domestic devices where sheet metal, particularly with double curvatures, is used.

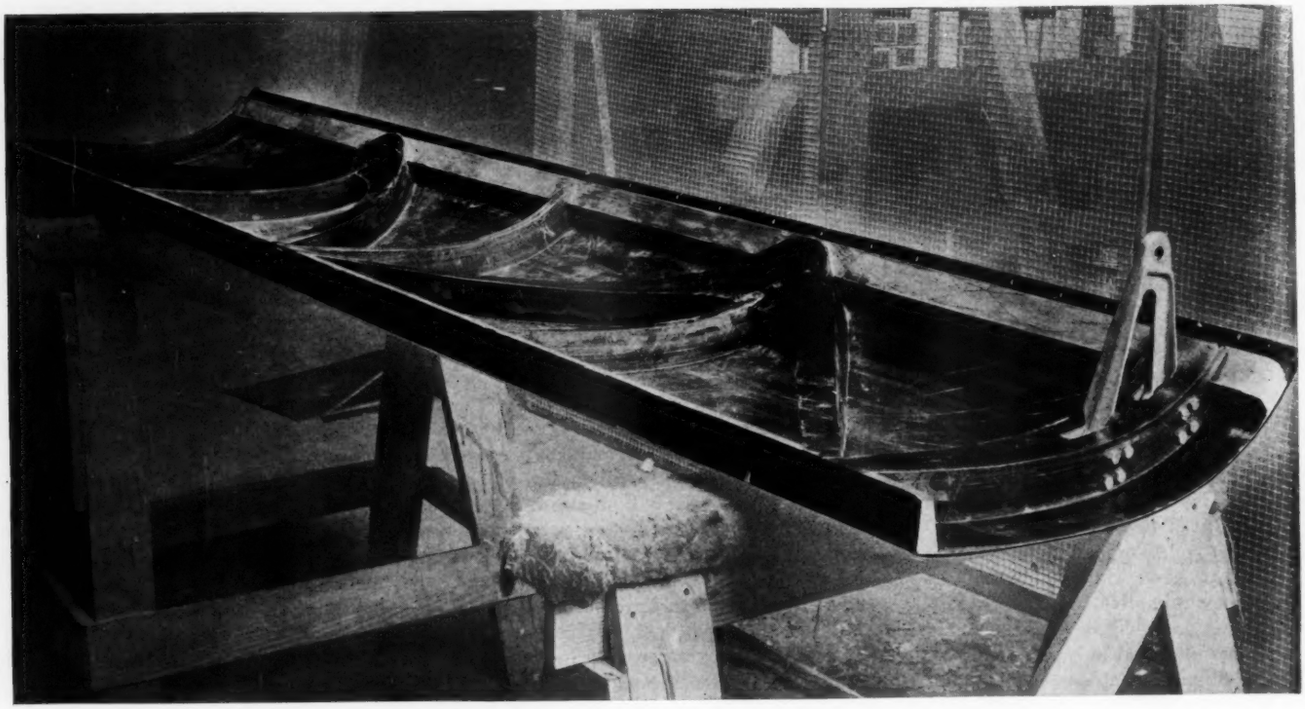


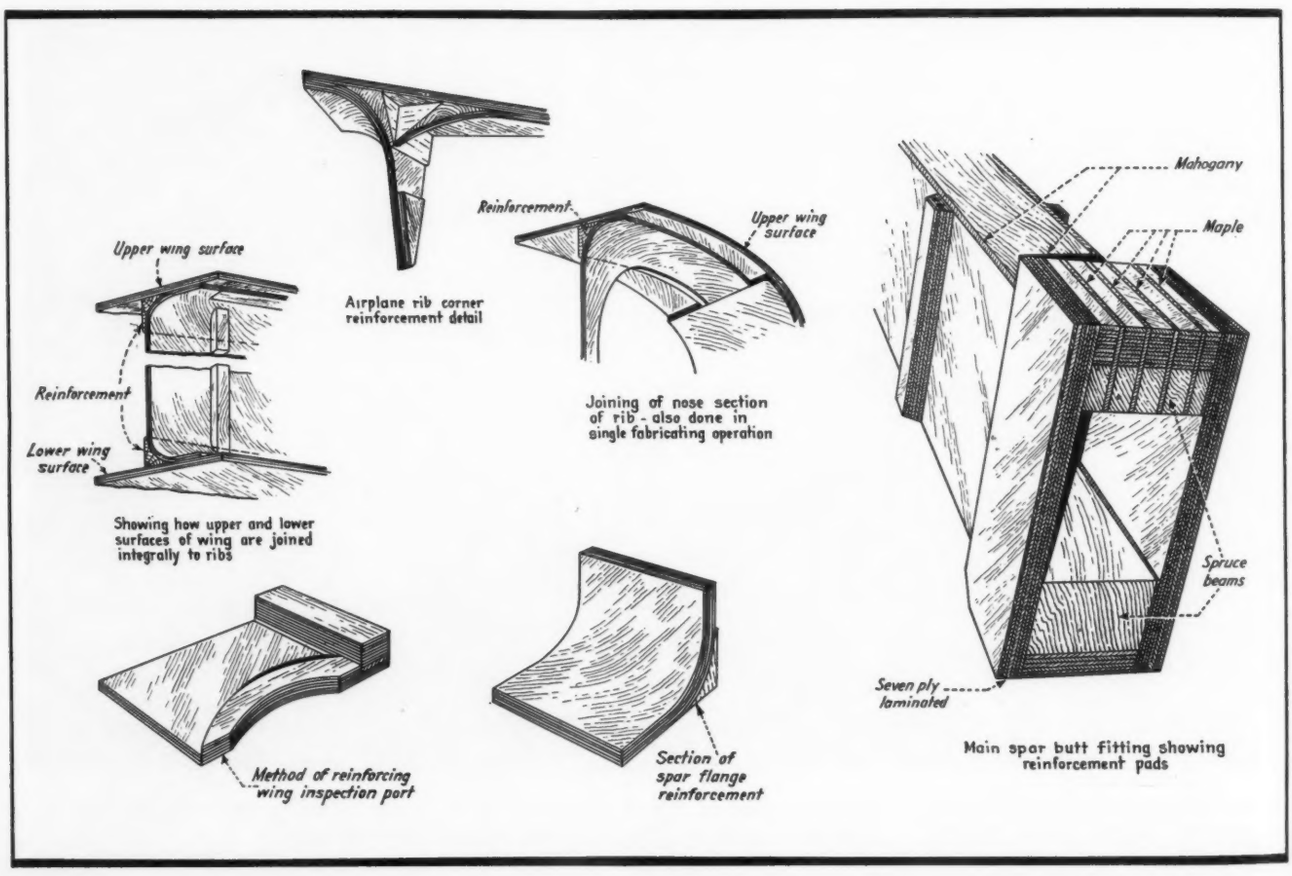
Rapid fabrication of broad, smooth, weatherproof surfaces of adequate strength, plus ease of assembly with standard fittings, led to the choice of laminated plywood for this Plymouth station wagon top. Designed by Aircraft Research, the top is fabricated by U.S. Plywood.

(*Continued on next page*)

Laminated Plastic Construction *(Continued)*

Pre-molded reinforcing braces with laminations 2 in. thick are joined to shell during the shell-forming operation in this bomb bay door. Construction, lighter than Dural, is of equal strength. Aircraft Research design.




Upper wing surface
Reinforcement
Lower wing surface
Showing how upper and lower surfaces of wing are joined integrally to ribs
Airplane rib corner reinforcement detail
Reinforcement
Upper wing surface
Joining of nose section of rib - also done in single fabricating operation
Mahogany
Maple
Spruce beams
Seven ply laminated
Main spar butt fitting showing reinforcement pads
Method of reinforcing wing inspection port
Section of spar flange reinforcement